STUDIES ON ROOT-KNOT NEMATODES OF VEGETABLE CROPS

ABSTRACT

THESIS SUBMITTED FOR THE DEGREE OF

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ABSTRACT

Studies were undertaken to examine the incidence and intensity of root-knot disease and to establish the identity of species and races of root-knot nematodes (*Meloidogyne* species) associated with vegetable crops in 8 districts in the State of Uttar Pradesh. Aligarh, Bulandshahr, Ghaziabad, Meerut, Muzaffarnagar, Saharanpur, Dehradun and Nainital districts, covering an area of 36,243 km^2 out of 2,94,364 km^2 (12.31%) of Uttar Pradesh and 1.104% of India, were selected as study area. This area is situated between 27^{o}29' and 29^{o}37N, and 77^{o}29 and 80^{o}5E. January is the coldest and June is the hottest month of the year in the area. Of 8 distrcits, 6 are located in the plains (altitude range 192 m to 942 m above the sea level) and 2 (Dehradun and Nainital) in the hilly tracts of Himalayas (altitude range 1967.4 m to 3022.5 m above the sea level). Localities with extensive vegetable cultivations in each district were surveyed and root samples of vegetable crops like tomato, eggplant, cucumber, okra, pepper, cabbage and cauliflower were collected. Species and races of root-knot nematodes (*Meloidogyne* spp.) prevalent in the area were identified and per cent infestation of vegetable fields in each district based on frequency of occurrence of root-knot nematodes in vegetable fields; incidence of root-knot nematodes on each vegetable crop in each district, and incidence of the disease based on infected root sample were calculated. An overall assessment of these aspects was also

made for the entire area. In addition, responses of some cultivars of vegetable crops to *M. javanica* and to all the 4 races of *M. incognita*, the two most frequent species of the area were investigated. A comparative assessment of root penetration of juveniles of *M. javanica* and *M. incognita* Race 1 in some cultivars of vegetables found susceptible and resistant/immune was also done. The effect of artificially created salinity levels of $NaHCO_3$ and NaCl on hatching, mortality, root penetration and development of *M. javanica* and *M. incognita* Race 2 and combined effects of the salinity levels and the root-knot nematodes on plant growth of okra and cucumber were also investigated.

Incidence and intensity of the disease

In general, a high percentage of fields grown with vegetables in the area were found infested with root-knot nematodes. Though the incidence of the disease showed a wide range of variations between the localities in each district, more than 50% of the fields grown with vegetables in the districts were infested with root-knot nematodes. The overall incidence of the disease in vegetable fields in the entire area was slightly above 60%. Incidence of the disease was also fairly high on each vegetable crop except cabbage and cauliflower. In each district above 50% fields of each vegetable crop except cabbage and cauliflower were infested. On root sample basis, the incidence of the disease was above 25% in each district. The disease incidence on each vegetable crop on root sample basis was above 28% except on cauliflower and cabbage, where it was 12.03% and 10.99% respectively. Overall incidence of the disease on root sample basis was above 35%.

Intensity of the disease on the basis of gall index (GI) and eggmass index (EMI) showed a wide range of variations. The GI ranged from 2-5 and EMI 0-5 on Taylor and Sasser scale. The intensity varied from field to field, crop to crop and from sample to sample. The intensity ranged from moderate to severe based on mean GI/EMI. Among the vegetable crops, intensity was highest on eggplant followed by okra, cucumber, tomato, and pepper in decreasing order. On cabbage and cauliflower, the disease intensity was low. Poor root galling and infrequent eggmass production were noticed on these crops.

Identity and frequency of the species

All the four major species of *Meloidogyne* viz., *M. incognita*, *M. javanica*, *M. arenaria* and *M. hapla* were found to exist in the area. *M. incognita*, *M. javanica* and *M. arenaria* were encountered in all the districts. But *M. hapla* was restricted to Dehradun and Nainital districts. Its occurrence was limited to localities situated at the hilly regions of both the districts. In both the localities of Nainital district (Bhawali and Nainital city area), *M. hapla* was more frequent than other species.

The species of root-knot nematodes were either found in single or mixed populations. Mixed populations of two species viz., *M. incognita* with *M. javanica*, *M. incognita* with *M. arenaria*, *M. incognita* with *M. hapla*, *M. javanica* with *M. arenaria*, *M. arenaria* with *M. hapla* or *M. incognita* with *M. javanica* and *M. arenaria* were encountered.

M. incognita was most frequent species in the area. It was dominant in all the districts except Bulandshahr where *M. javanica* dominated. *M. arenaria* was third in order of dominance. *M. hapla* was least frequent in the area restricted to hilly localities of Nainital and Dehradun districts. Regardless of single or mixed infection in total samples collected from all the districts, 72.26% root samples were infected with *M. incognita*, 44.30% with *M. javanica* and 25.43% with *M. arenaria*. *M. hapla* was found only in 4.71% of the root samples. Single populations of *Meloidogyne* species was encountered more frequently than their mixed populations. Frequency of single and mixed populations was 57.59% and 42.40% respectively. Among the mixed populations of different combinations of species *M. incognita* and *M. javanica* were most frequent, followed by mixed populations of *M. incognita* and *M. arenaria*. The frequency of the former combination was 19.39% and of the latter 9.49%.

Identity and frequency of the races

Existence of Race 1, Race 2, Race 3, Race 4 of *M. incognita* and Race 2 of *M. arenaria* was recorded in the area included in the study. Race 1, Race 2 and Race 4 of *M. incognita* were present in all the districts. Race 3 was absent from Dehradun and Nainital districts. It was, however, present in other districts. Race 2 of *M. arenaria* was found in all the districts. Existence of Race 1 in *M. arenaria* populations in the area was not found. Amongst the races of *M. incognita*, Race 1 was most frequent. Race 2 emerged as the second most common race of *M. incognita*. It was followed by Race 4. Race 3 was least frequent. In the area, per cent occurrence was 34.63, 26.67, 21.01 and 17.69 for Race 1, Race 2, Race 4 and Race 3 respectively. Race 2 was invariably detected in all *M. arenaria* populations. Consequently its frequency was 100%.

With variations in specific localities of the districts, Race 1 of *M. incognita* was most frequent in Aligarh, Bulandshahr, Ghaziabad, Saharanpur but Race 2 was dominant in Muzaffarnagar and Meerut and Race 4 in Dehradun and Nainital. Race 3 was less frequent than Race 1 and Race 2 in all the districts except Bulandshahr and Saharanpur. Its frequency was equal to Race 1 in Bulandshahr and more than Race 2 both in Bulandshahr and Saharanpur. Race 4 was more frequent than Race 3 in Aligarh, Ghaziabad, Meerut, and less frequent in Bulandshahr, Muzaffarnagar and in Saharanpur. *M. arenaria* Race 2 was present in all the districts. Its frequency was highest in Muzaffarnagar followed by Meerut, Nainital, Saharanpur, Aligarh, Ghaziabad, Dehradun and Bulandshahr.

Occurrence of *M. hapla* and Race 1, Race 2, Race 3 of *M. incognita* in the State of Uttar Pradesh is reported for the first time. Records of Race 4 of *M. incognita* and Race 2 of *M. arenaria* are new for India as well as for the State of Uttar Pradesh.

Response of cultivars of vegetables

Thirty six cultivars of tomato, 19 of eggplant, 14 of pepper, 10 of okra, 9 of cucumber, 37 of cauliflower and 23 of cabbage were screened against *M. javanica* and Race 1, Race 2, Race 3 and Race 4 of *M. incognita* in artificial inoculations to evaluate their degree of resistance and host suitability designations (resistance) were assigned to cultivars according to modified Canto-Saenz scheme. Most of the cultivars of the vegetables screened were susceptible. All the cultivars of eggplant and okra screened were susceptible to all the test nematodes. Some of the cultivars of tomato, pepper, cucumber, cauliflower and cabbage, however, showed race-specific resistance to *M. incognita* and to *M. javanica*.

Ten cultivars of tomato viz., Pusa-120, Calmart VFN, Panjab 6.NR-7, EC173898 (72T6), EC173897 (Calmart), EC173896 (Kewalo), CLN363BC$_1$F$_2$-167-1-0, CLN363BC$_1$F$_2$-190-1-0, CLN363-BC$_1$F$_2$-344-0-0 and CLN229BC$_1$F$_2$-4-1-4-0 were immune and 2 cultivars namely VFN-Bush and VFN-8 were resistant to all the test nematodes. Pelicon was resistant to Race 1, Race 2 and Race 4 of *M.incognita*; tolerant to Race 3 of *M. incognita* and immune to *M. javanica*. In pepper, two cultivars Jwala and Pusa Jwala showed resistance. Jwala was resistant to all the 4 races but Pusa Jwala was resistant to Race 1 and Race 3 of *M. incognita*. Against *M. javanica*, five cultivars of pepper (Jwala, Bull Nose, Chinese Giant, Chilli N-P.46-A and Suryamukhi) were found immune and five cultivars (Pusa Jwala, Suryamukhi Black, Hungarian Wax, Chilli G-3 and California Wonder) resistant. Rest of the cultivars were susceptible.

In cucumber, except Improved Long Green, all the cultivars were found susceptible to the test nematodes. Improved Long Green exhibited resistance to *M. javanica* and hypersusceptibility to Race 3 of *M. incognita*. One cultivar of cauliflower (Dania) and one of Cabbage (American Special Ballhead) were immune and resistant to all the test nematodes respectively. A number of cultivars of both the crops were, however, found resistant to one or the other test nematodes.

A marked significant difference in the rate of juvenile penetration in relation to time, total penetration, rate of development and attaining of maturity of females was found, when juvenile penetration and post-penetration development of *M. incognita* Race 1 and *M. javanica* in roots of susceptible and resistant/immune cultivars of some vegetables were assessed. Root penetration by juveniles of both the nematodes in resistant/immune cultivars was significantly poor in comparison to susceptible cultivars of the same vegetable. The development of juveniles of *M. incognita* Race 1 or *M. javanica* in the roots of resistant cultivars of vegetables was delayed and only a few matured into adult females.

Effect of soil salinity

Effect of four different concentrations (1.5, 2.5, 3.5 and 5.0 mmhos/cm) of NaCl and $NaHCO_3$ were tested on juvenile hatching and mortality of *M. javanica* and *M. incognita* Race 2. All the concentrations of both the salts suppressed juvenile hatching of both the nematodes. A direct correlation between juvenile hatching and concentration of the salts was recorded.

Highest juvenile hatch suppression was noticed in 5.0 mmhos/cm. All the salt concentrations induced juvenile mortality of both the species. Highest mortality was found in 5.0 mmhos/cm. Per cent mortality increased in all the concentrations with an increase in exposure period.

Effects of 1.5, 2.5, 3.5 and 5.0 mmhos/cm of both the salts was studied on penetration of juveniles (J_2) in the roots of cucumber and okra. All the salt concentrations tested adversely affected the juvenile penetration of roots of okra and cucumber. It was true for both the nematodes. A direct correlation existed between the concentration of salt and the number of ingressed juveniles in the roots. Under the influence of salinity, the development of juveniles into adult females and production of eggmasses were delayed. In contrast to control, very few eggmass were produced in all the treatments due to adverse influence of salts.

Soil salinity levels (3.5 and 5.0 mmhos/cm) artificially created by addition of NaCl and $NaHCO_3$ retarded plant growth of okra and cucumber. The higher salinity level was more inhibitory for plant growth. *M. javanica* as well as *M. incognita* Race 2 caused appreciable reduction in plant growth parameters of both the crops. The reduction in growth parameters of both the crops caused by the nematodes was reduced in the presence of soil salinity. Consequently, under the combined influence of soil salinity and root-knot nematodes growth of both crops was better than the plants inoculated with root-knot nematodes alone.

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1988

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CERTIFICATE

This is to certify that Mr. Abrar Ahmad Khan has worked in this department as a Research Scholar under my supervision and guidance. His work on " Studies on root-knot nematodes of vegetable crops" is upto-date and original. He is allowed to submit his thesis for consideration of the award of the degree of Doctor of Philosophy in Botany.

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SECTION II

GENERAL INTRODUCTION

One of the greatest challenges faced by the world today is feeding of an ever-increasing population. Low agricultural productivity in developing countries and inadequate means of food distribution contribute greatly to this problem. Low yielding varieties, poor soil fertility, semi-or non-mechanized farming, traditional methods of farming and inadequate pest management practices are some of the factors responsible for low productivity (Sasser and Carter, 1985). Root-knot nematodes (*Meloidogyne* species) are one of the most widespread pathogens limiting world agricultural productivity. Almost all of the plants that account for the majority of the world's food supply are susceptible to this group of pathogens (Taylor and Sasser, 1978; Sasser *et al*., 1982; Taylor *et al*., 1982). In areas where root-knot nematodes are not controlled average crop yield losses are estimated to be about 25 per cent with damage in individual fields ranging as high as 60 per cent (Sasser, 1980; Sasser and Carter, 1982).

Since root-knot nematodes occur throughout the world, infect all major crop plants and cause substantial reduction in crop yield and quality, the North Carolina State University at Raleigh (U.S.A.) in 1975 initiated an international project known as International *Meloidogyne* Project (IMP), to investigate the various aspects of the problem on worldwide basis. This project was funded by the United States Agency for International

Development (USAID). With the cooperation of nearly 100 nematologists from 70 countries of the world, investigations on root-knot nematodes were carried out under the aegis of IMP till its termination in 1984. The project achieved its main objective in identifying the species and races of *Meloidogyne* causing damage to various crops in different parts of the world. Four species of root-knot nematodes viz., *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949; *Meloidogyne javanica* (Treub, 1885) Chitwood, 1949; *Meloidogyne arenaria* (Neal, 1889) Chitwood, 1949; and *Meloidogyne hapla* Chitwood, 1949 were recognized as major root-knot nematode species of international importance. These species comprised about 95% of the total *Meloidogyne* populations obtained from different countries of the world and analysed at the IMP headquarters at Raleigh (Carter and Sasser, 1982). In 1984 a new replacement project called Crop Nematode Research & Control Project (CNRCP) was started at Raleigh initially for three years to look for the suitable and effective measures to solve the problems of root-knot nematodes on various crops in different parts of the world utilizing the information gained through IMP researches. This project is, however, still continuing after extension by the funding agency, USAID.

Although all the four major species of *Meloidogyne* are known to exist in India, their identity and relative importance on various crops in different agro-climatic zones of the country have not been thoroughly investigated and documented.

Available information in this respect in the country is scanty and fragmentary. Eleven species of *Meloidogyne* have been reported attacking a large number of host plants in the country (Sitaramaiah, 1984). Out of the eleven, only three species, *M. incognita*, *M. javanica* and *M. graminicola* Golden and Birchfield, 1965 are predominant in India. *M. incognita* and *M. javanica* have been found to attack mostly vegetables, whereas *M. graminicola* is confined to rice (Krishnappa, 1985). This picture of their occurrence and dominance has emerged from a relatively very few studies. Similarly, there have been very limited studies on differentiation of races in *M. incognita* populations. Such information is partly available from the States of Andhra Pradesh, Haryana, Karnataka, Madhya Pradesh, Orissa, and Tamil Nadu out of the 25 States in the country.

Krishnappa (1982) studied samples of root-knot infected crops collected from different places in the State of Karnataka as well as some samples from the States of Madhya Pradesh, Tamil Nadu and Andhra Pradesh. In all the 40 samples studied, *M. incognita* was invariably found as the causal species. Three races i.e. Race 1, Race 2, and Race 3 were identified in *M. incognita* populations. Race 1 was most prevalent. Race 2 and Race 3 showed limited distribution each being present only in one of the localities in the State of Karnataka. A later report indicated the occurrence of Race 1 and Race 3 of *M. incognita* in the State of Karnataka (Krishnappa and Setty, 1983). In the State of Orissa, around Bhubaneshwar, occurrence of Race 1 and

Race 2 of *M. incognita* was recorded by Routray and Das (1982). Race 1 of *M. incognita* has been recorded to exist in the State of Haryana (Raja and Gill, 1982). Isolates of *M. incognita* from Jaipur, Jodhpur, Sriganganagar and Udaipur areas in the State of Rajasthan differed in pathogenicity in host differential tests carried out by Parihar and Yadav (1986) which suggested the presence of races in the isolates. But races were, however, not designated by them. Krishnappa (1985) while reviewing the work done in IMP region VIII (India) advocated for the need of collections and characterization of as many as possible populations from different hosts in each State of India for identification of species and races of *Meloidogyne* and assessment of frequency and distribution of root-knot nematodes.

Since the responses of host cultivars to different species of *Meloidogyne* and their races are likely to be variable, it is essential to know the occurrence of species of *Meloidogyne* and their races in a given area. The establishment of the identity of *Meloidogyne* spp. in different parts of India is a matter of fundamental importance for successful cultivation of various crops vulnerable to attack by root-knot nematodes. At the same time, relative dominance of the species of *Meloidogyne* and their races, their pattern of distribution and concentration in different agro-climatic zones of the country need to be investigated and documented. This is more true for North India, particularly in the Indo-Gangetic plains of Uttar Pradesh, the area with most extensive and intensive agriculture in India.

Responses of host cultivars, being grown in different States of India, to species and races of *Meloidogyne* known to exist in the State or country have not been ascertained and it demands sufficient study. Commercial cultivars being grown by farmers and the new cultivars before introduction should be screened against the species and known races of *Meloidogyne*. Before recommending cultivars for commercial cultivation, information regarding their performance against different species and races of *Meloidogyne* is necessary and should be provided to growers. Some attempts had been made to screen cultivars of vegetables like bean, tomato, eggplant, pepper, cowpea, okra cucumber, cauliflower, cabbage, carrot, radish etc. against the species of root-knot nematodes. Since there has been very little effort to identify the races in *Meloidogyne* spp. in India, screening of cultivars grown in India against the known races has not been attempted.

Soil salinity is a serious problem in certain parts of India including Uttar Pradesh and attempts are being made to reclaim these lands, popularly known as " Usar" lands. High salt content of these lands debilitate the grown plants. The interaction of high salt content and the root-knot nematodes has received little study. There are, however, some reports which indicate that infectivity and development of *M. incognita* are impaired by increasing soil salt concentration (Edongali *et al.*, 1982). This aspect needs to be examined using different species and races of root-knot nematodes in relation to various crops.

In view of the above, the following three major aspects have been studied:

1. Incidence and intensity of root-knot disease and identity of species and races and their pattern of distribution in some parts of the Western Uttar Pradesh.

2. Relative susceptibility of some cultivars of vegetable crops to species and races of *Meloidogyne*.

3. Soil salinity in relation to root-knot nematode development and crop productivity.

Three different but related aspects of the root-knot nematode problem, studied for Ph.D. programme are presented in three sections each with separate introduction (including literature review), materials and methods, results, discussion and summary in the thesis. In order to avoid duplication, the literature cited in the text of all the three sections, however, are presented jointly at the end of the thesis.

SECTION I

INTRODUCTION

Root-knot nematodes are one of the most important groups of plant nematodes and infect an array of plants of economic importance all over the world. Due to their small size and protective habitat root-knot nematodes remained undiscovered until the nineteenth century even though they cause quite recognisable galls. Root-knot disease was first recorded by Berkeley (1855) on glasshouse cucumbers in England. Since then the pathogens have been designated for a considerably long period of time with different names (Sasser and Carter, 1982; Triantaphyllou, 1982; Hirschmann, 1985).

The present day name *Meloidogyne* was given by Goeldi (1887). Chitwood (1949), on the basis of morphological differences, particularly in the cuticular markings of the perineal region of adult females, described four species viz. *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949; *M. javanica* (Treub,1885) Chitwood, 1949; *M. arenaria* (Neal, 1889) Chitwood, 1949; *M. hapla* Chitwood, 1949 and one sub-species. Since then from time to time new species were discovered, described and added to the species list of the genus. Whitehead (1968) listed 23 species; Franklin (1972) 32 species; Taylor and Sasser (1978) 36 species; and Triantaphyllou (1982) 50 species and two sub-species. By June 1984, the species index of the genus included 54 species and two sub-species (Hirschmann, 1985). Since 1985, 14 more species have been added to the list (Golden and Handoo, 1984; Lopez, 1984; Toida and Yaegashi, 1984; Pan, 1985; Sagalina *et al*., 1985; Eisenback *et al*., 1985; Golden and Kaplan, 1986; Kleynhans, 1986; Zhang and Su, 1986; Hirschmann, 1986; Abdel-Rahman and Maggenti, 1987; Jepson, 1987; and Jepson and Golden, 1987).

Sasser (1977) summarized the distribution of root-knot nematode species in different parts of the world. The summary included the occurrence of 11 species in Africa, 9 species in Central and South America, 18 species in the United States, 3 species in Canada, 11 species in Europe and the Mediterranean region, 10 species in India and Sri Lanka, 4 species in Russia, 5 species in Japan and 3 species in Southeast Asia, Australia and Fiji Islands.

In view of the international importance of root-knot nematodes, an International *Meloidogyne* Project (IMP) funded by USAID was started under the leadership of Prof. J.N.Sasser of the Department of Plant Pathology, North Carolina State University at Raleigh, U.S.A. with the main goal of assisting the developing nations in increasing yields of economic food crops. Over 100 nematologist from universities and research institutes of 76 countries around the world collaborated with IMP. Eight geographical regions of the IMP namely Region I - Mexico, Central America and Caribbean, Region II - South America excluding Brazil, Region III - Brazil, Region IV - West Africa, Region V - East Africa, Region VI - Asia, Region VII - Mediterranean and the Middle East and Région VIII - India were established. Regional conferences were conducted periodically in each of these regions for the planning of objectives and the discussion of research findings (Sasser and Carter, 1985).

Approximately, 1300 live populations of Meloidogyne species obtained from 100 cooperators representing more than 70 developing nations were studied at IMP headquarters at Raleigh. Out of 914 samples identified frequency of species encountered was as follows: M. incognita 52%, M. javanica 31%, M. hapla 8%, M. arenaria 7%, M. exigua 1%, and others, such as M. graminicola, M. megatyla, M. microtyla, M. naasi, M. graminis and M. oryzae 1%. Four races designated as Race 1, Race 2, Race 3 and Race 4, were differentiated in M. incognita. Race 1 comprised 72% of 472 populations studied, Race 2, 13%; Race 3, 13% and Race 4, 2%. With in the species M. arenaria, two races (Race 1 and Race 2) were distinguished. Race 1 comprised 16% and Race 2, 84% of 70 populations studied (Sasser, 1982). Sasser (1982) emphasized that researches on root-knot nematodes in agricultural soils must hereafter take into consideration the existence of host races.

About 95% of the populations identified through the efforts of the International Meloidogyne Project (IMP), collected from agricultural soils around the world were represented by only four species: Meloidogyne incognita, M. javanica, M. arenaria and M. hapla (Taylor et al., 1982). The first two species were found to be widely distributed in tropical, sub-tropical and warm temperate climates of the world. *M. arenaria* was also encountered in such climates but it was relatively less frequent. All three of these species occurred in areas with an average temperature of 36°C or lower in the warmest month. *M. hapla* was found in temperate climate. It occurred in areas with an average temperature of 15°C during the coldest month, but was limited to areas with an average temperature of less than 27°C during the warmest month (Taylor *et al.*, 1982).

The project was concluded in 1984 after functioning for 9 years. The pictures that have emerged from the studies under the coordination of IMP in different countries or IMP regions with regard to number of species and races present in the region, their pattern of distribution and relative dominance are summarized below. This, however, includes some informations on these aspects that were available before the studies started under the aegis of IMP. Species and races of root-knot nematodes recorded in different IMP regions of the world are given in the Table (1). Records of occurrence of species and races of root-knot nematodes in different countries of the various IMP regions are presented in Tables 2-9.

In the Region I, which included Bermuda, Costa Rica, El-Salvador, Guadeloupe, Jamaica, Mexico, Panama, Puerto Rico, Surinam and Trinidad, *M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. exigua*, *M. kikuyensis*, *M. chitwoodi*, and *M. oryzae*

Table 1. Species and races of root-knot nematodes (*Meloidogyne* species) recorded in the IMP regions of the world.

Region	Country	Species	Races of *M.incognita*	Races of *M.arenaria*
I- Mexico, Central America, and Caribbean	Bermuda, Costa Rica, El-Salvador, Guadeloupe, Jamaica, Mexico, Panama, Puerto Rico, Surinam, Trinidad	*M.incognita*, *M.javanica* *M.arenaria*, *M.hapla*, *M.exigua*, *M. kikuyensis* *M.chitwood*, *M. oryzae*	1,2,3,4	2
II- South America exluding Brazil	Argentina, Bolivia, Chile, Colombia, Ecuador Peru, Uruguay, Venezeula	*M.incognita*, *M.javanica*, *M.arenaria*, *M.hapla*, *M.exigua*, *M.decalineata* *M.naasi*, *M.incognita acrita*	1,2,3,4	2
III-Brazil	Brazil	*M.incognita*, *M.javanica*, *M.arenaria*, *M.hapla*, *M.exigua*, *M.thamesi*, *M.bauruensis*, *M.inornata*, *M.coffeicola*, *M.lordelloi*, *M.elegans*	1,2,3,4	2
IV- West Africa	Benin Republic, Ghana, Ivory Coast, Liberia, Nigeria, Senegambia	*M.incognita*, *M.javanica* *M.arenaria*, *Meloidogyne* spp.*	1,2,3,4	2
V- East Africa	Kenya, Malawi, Tanzania, Uganda, Zimbabwe	*M.incognita*, *M.javanica*, *M.arenaria*, *M.hapla*, *M.decalineata*, *M.africana* *M.acronea*, *M.kikuyensis*, *M.incognita acrita*, *M.ethiopica*	1,3	

Contd.

Table 1 (Continued).

Region	Country	Species	Races of *M.incognita*	Races of *M.arenaria*
VI- Asia	Bangladesh, Burma, Fiji Island, Indonesia, Japan, Korea, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, Taiwan, Thailand	*M.incognita*, *M.javanica* *M.arenaria*, *M. hapla*, *M.graminicola*, *M.megatyla* *M.brevicauda*, *M.incognita acrita*, *M.exigua*, *M.naasi*	1,2,3,4	2
VII-Mediterranean and Middle East	Algeria, Cyprus, Egypt, Greece, Iran, Iraq, Italy, Jordan, Libya, Morocco, Portugal, Saudi Arabia, Spain, Sudan, Syria, Tunisia, Turkey, Yemen.	*M.incognita*, *M.javanica* *M.arenaria*, *M.hapla*, *M.naasi*, *M.thamesi*, *M.artiellia*, *M.megadora*, *M.exigua*, *M.africana*, *M.incognita acrita*	1,2,3,4	1,2
VIII-India	India	*M.incognita*, *M.javanica*, *M.arenaria*, *M.hapla*, *M.graminicola*, *M.incognita acrita*, *M.thamesi*, *M.indica*, *M.exigua*, *M.africana*, *M.brevicauda*, *M.lucknowica*, *M.graminis*	1,2,3	

* *Meloidogyne* spp. = unidentified or referred to as 'rice *Meloidogyne*'

were recognized to be present. The first four species were found to be most common. All the four races of *M. incognita* viz. Race 1, Race 2, Race 3, and Race 4; and Race 2 of *M. arenaria* were identified to exist in the region (Table 2). Sosa-Moss (1985) summarized the occurrence of species of root-knot nematodes and their races in this region. Burpee (1981) reported *M. incognita* Race 1 and *M. arenaria* Race 2 in Bermuda. Race 1 of *M. incognita*, *M. hapla*, *M. exigua* and *M. javanica* were recognized from Costa Rica (Lopez, 1981; Alvardo *et al.*, 1982). In El-Salvador, Abergo (1976) reported the presence of *M. incognita* Race 1, 2 and 3. From Guadaloupe, *M. incognita* (Race 1), *M. javanica* and *M. arenaria* (Race 2) were recorded (Anais, 1982; Kermarrec, 1981). *M. incognita* (Race 1) was claimed as predominant.

M. incognita Race 1, 2 and 3, *M. javanica*, *M. arenaria* and *M. hapla* were reported from Jamaica (Dixon and Latta, 1965; Hutton, 1976, 1981). Race 1 of *M. incognita* was found as a most common race in the country. In Mexico, *M. incognita* Race 1 and 3, *M. javanica*, *M. arenaria* and *M. hapla* were reported by Sosa-Moss (1982). *M. exigua*, *M. kikuyensis* and *M. chitwoodi*, were also identified to exist in the country (Sosa-Moss, 1985). Race 1 and 2 of *M. incognita* were detected in Panama (Tarte, 1981). Puerto Rico is the only country in the Region where occurrence of all the four races of *M. incognita* were recorded (Acosta and Negron, 1982; Ayala, 1981; Ayala *et al.*, 1982). Ayala (1976,1981) also identified *M. arenaria* Race 2 from the country. In Surinam M. incognita Race 1, M. javanica and M. arenaria Race 2 were the species of root-knot nematodes (Oever, 1982). Oever (1982) also reported M. oryzae on rice in the country. In Trinidad, M. incognita Race 1 and 2 and M. javanica were found to exist (Singh, 1981) (Table 2).

In the Region II which consisted of 8 countries of South America (Table 3), M. incognita, M. javanica, M. arenaria, M. hapla, M. exigua, M. decalineata, M. incognita acrita and M. naasi were found to be present (Cabanillas, 1985). All the four races of M. incognita, and Race 2 of M. arenaria were detected. Costilla (1982) reported the presence of M. javanica, M. incognita and M. arenaria in the north eastern part of Argentina, M. javanica was predominant. M. hapla and M. decalineata were detected only once in minor infestations of potato and of bean respectively. Race 1 and Race 2 of M. incognita were differentiated. M. hapla, M. incognita, M. javanica, M. arenaria (Race 2) and M. incognita acrita were found in Bolivia (Cabanillas, 1985; Taylor et al., 1982). M. incognita Race 2, M. hapla, M. arenaria, M. javanica and M. naasi were predominant species in Chile (Gonzalez, 1982).

In Colombia, M. incognita Race 2 was present on carnation, bean, banana, potato and tomato trees. M. incognita Race 1 was identified in beans and M. incognita Race 4 in tomato tree. M. javanica was infecting beans, banana and tomato tree. M. exigua and M. hapla were existing on coffee and red pepper (Capsicum vacatum) respectively (Navarro, 1982). In Ecuador,

Table 2. Species and races of *root-knot nematodes* (*Meloidogyne* species) recorded in the IMP Region I (Mexico, Central America and Caribbean).

Country	Species of *Meloidogyne*	Races of *M. incognita*	Races of *M. arenaria*	Reference
Bermuda	*M.incognita*, *M.arenaria*	1	2	Burpee (1981)
Costa Rica	*M.incognita*, *M.javanica*, *M.hapla* *M.exigua*	1	-	Lopez (1981) Alvardo *et al.* (1982)
El-Salvador	*M.incognita*	1,2,3	-	Abergo (1976)
Guadeloupe	*M.incognita*, *M.javanica*, *M.arenaria*	1	2	Anais (1982), Kermarrec (1981)
Jamaica	*M.incognita*, *M.javanica*, *M.arenaria* *M.hapla*	1,2,3	-	Dixon and Latta (1965), Hutton (1976,1981)
Mexico	*M.incognita*, *M.javanica*, *M.arenaria* *M.hapla*, *M.exigua*, *M.kikuyensis* *M.chitwoodi*	1,3	-	Sosa-Moss (1982,1985)
Panama	*M.incognita*	1,2	-	Tarte (1981)
Puerto Rico	*M.incognita*, *M.arenaria*	1,2,3,4	2	Acosta and Negron (1982) Ayala (1976;1981), Ayala *et al.*, (1982)
Surinam	*M.incognita*, *M.javanica*, *M.arenaria*, *M.oryzae*	1	2	Oever (1982)
Trinidad	*M.incognita*, *M.javanica*	1,2	-	Singh (1981)

- = Information about races of *M. arenaria* not available.

M. *incognita* (Race 1) was found as predominant species and M. *incognita* (Race 2), M. *javanica*, M. *arenaria* and M. *hapla* were restricted to certain crops and zones (Rodriguez, 1982; Cabanillas, 1985). In Peru, Guerra (1982) reported the existence of M. *incognita*, M. *javanica*, M. *arenaria* and M. *hapla*, the first two being of major occurrence in cultivated plots as well as valleys. All the four races of M. *incognita* and Race 2 of M. *arenaria* were identified in the country (Jatala, 1982). In Uruguay, M. *incognita* Race 1 and 3, M. *javanica* and M. *arenaria* Race 2 have been identified from the country (Taylor *et al.*, 1982; Cabanillas, 1985). In Venezuela, *Meloidogyne* species that have been identified were M. *hapla* and M. *incognita* Race 1 (Taylor *et al.*, 1982) (Table 3).

In Region III, which included only Brazil, eleven species of root-knot nematodes and all the four races of M. *incognita* and Race 2 of M. *arenaria* were recorded to exist in the country (Table 4). But M. *incognita* and M. *javanica* were recognized as most wide-spread and important species of root-knot nematodes (Ferraz, 1985).

Prior to the start of work in cooperation with IMP in Brazil, Boock (1951) had reported the occurrence of M. *incognita* in potato tubers. Similarly M. *javanica*, M. *hapla*, and M. *arenaria* were first identified by Carvalho (1954) on soybean roots. Lordello (1956) described M. *javanica*, M. *bauruensis* as a parasite of soybean var. Aburo. From the same host

Table 3. Species and races of root-knot nematodes (*Meloidogyne* species) recorded in the IMP Region II (South America).

Country	Species of *Meloidogyne*	Races of *M. incognita*	Races of *M. arenaria*	Reference
Argentina	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. decalineata*	1,2	–	Costilla (1982)
Bolivia	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. incognita acrita*	–	2	Taylor *et al.* (1982), Cabanillas (1985)
Chile	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. naasi*	2	–	Gonzalez (1982)
Colombia	*M. incognita*, *M. javanica*, *M. hapla* *M. exigua*	1,2,4	–	Navarro (1982)
Ecuador	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*	1,2	–	Rodriguez (1982) Cabanillas (1985)
Peru	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*	1,2,3,4	2	Guerra (1982), Jatala (1982)
Uruguay	*M. incognita*, *M. javanica*, *M. arenaria*	1,3	2	Taylor *et al.* (1982), Cabanillas (1985)
Venezuela	*M. incognita*, *M. hapla*	1	–	Taylor *et al.* (1982)

– = Information about races of *M. incognita* or *M. arenaria* not available.

cultivated in Campinas, he later described another new species *M. inornata* (Lordello, 1956). Lordello and Zamith (1958) found *M. exigua* attacking coffee trees in the State of Sao Paulo. Lordello and Zamith (1960) described *M. coffeicola*, a new species that was causing the death of coffee trees in the State of Parana. *M. thamesi* was found parasitizing *Artocarpus incisa* in Pernamuco. A new species, *M. lordelloi* was described by Ponte (1969) as parasite of a cactus, *Cereus macrogonus*, in the State of Ceara and another new species *M. elegans* in 1977 (Ponte, 1977) (Table 4).

In the Region IV which comprised of 14 countries, only six countries viz., Benin Republic, Ghana, Ivory Coast, Liberia, Nigeria and Senegambia were actively involved in cooperation with IMP. Egunjobi (1985) while summarizing the work done in these countries, indicated that four species of *Meloidogyne* reported to occur in the region were *M. incognita*, *M. javanica*, *M. arenaria* and one unidentified species referred to as " rice *Meloidogyne*" . Of these, the most wide-spread was *M. incognita*. All the four races of *M. incognita* and Race 2 of *M. arenaria* were also recorded in the region (Egunjobi, 1985). In Benin, root-knot nematodes were recognized as major problem on many vegetables but species were not identified (Zannou and Dodego, 1981). In Ghana, Hemeng and Hemeng (1976) found *M. incognita*, accounting for about 67% of the country's collections. Hemeng (1976) reported that it was found alone as well as in mixed population with *M. javanica* in the forest zone and in the Greater Accra Zone. All the four races of *M. incognita* were

Table 4. Species and races of root-knot nematodes (Meloidogyne species) recorded in the IMP Region III (Brazil).

Country	Species of Meloidogyne	Races of M. incognita	Races of M. arenaria	Reference
Brazil	M. incognita, M. javanica , M. arenaria , M. hapla, M. coffeicola, M. lordelloi, M. exigua, M. thamesi, M. bauruensis, M. elegans, M. inornata	1,2,3,4	2	Book (1951), Carvalho (1954), Lordello (1956), Lordello and Zamith (1958,1960), Ponte (1969,1977), Ferraz (1985)

detected in the country. Meloidogyne sp. was major problem with upland rice in Ivory Coast. The other identified species were M. incognita (Race 1 and 2), M. javanica, and M. arenaria (Race 2) (Merney, 1976; Fortuner, 1981). Neiuwenhuyzen (1976) reported M. incognita Race 2 and M. javanica from Liberia. Three species of root-knot nematodes, M. incognita, M. javanica and M. arenaria in the order of abundance were recorded in Nigeria (Ogunfowora, 1981). M. incognita Race 1 and Race 2 were more prevalent in South Nigeria and M. javanica in Northern Nigeria (Caveness, 1978; Ogbuji and Diarua, 1978; Ogunfowora, 1978). Fortuner (1981) reported that Meloidogyne sp. was one of the most important parasite on upland rice in the country. M. incognita, M. javanica, and M. arenaria were reported to occur in Senegambia (Egunjobi, 1985) (Table 5).

Saka (1985) summarized the occurrence of Meloidogyne species in the Region V which included 7 countries but information is available only from five countries, viz., Kenya, Malawi, Tanzania, Uganda, and Zimbabwe. M. incognita, M. javanica, M. arenaria, M. hapla, M. decalineata, M. africana, M. acronea, M. kikuyensis, M. incognita acrita, and M. ethiopica were known to be present in the region. Race 1, and 3 of M. incognita were found in the region (Saka, 1985). In Kenya, De Grisse (1960) described a new root-knot nematode, M. kikuyensis found attacking Kikuga grass. Ngundo (1976) reported M. incognita and M. javanica on beans in the country. In Malawi, M. javanica and M. incognita have been recognized as widely distributed

Table 5. Species and races of root-knot nematodes (*Meloidogyne* species) recorded in the IMP Region IV (West Africa).

Country	Species of *Meloidogyne*	Races of *M. incognita*	Races of *M. arenaria*	Reference
Benin	*Meloidogyne* spp.	-	-	Zannou and Dodego (1981)
Ghana	*M. incognita*, *M. javanica*	1,2,3,4	-	Hemeng and Hemeng (1976). Hemeng (1976)
Ivory Coast	*M. incognita*, *M. javanica*, *M. arenaria*, *Meloidogyne* sp.*	1,2	2	Merney (1976), Fortuner (1981)
Liberia	*M. incognita*, *M. javanica*	2	-	Neiuwenhuyzen (1976)
Nigeria	*M. incognita*, *M. javanica*, *M. arenaria* *Meloidogyne* spp.	1,2	-	Ogunfowora (1978,1981), Caveness (1978), Ogbuji and Diarua (1978). Fortuner (1981)
Senegambia	*M. incognita*, *M. javanica*, *M. arenaria*	-	-	Egunjobi (1985)

* *Meloidogyne* sp. = referred to as 'rice *Meloidogyne*'

\- = Information about races of *M. incognita* or *M. arenaria* not avaialble species (Martin, 1960, Saka, 1981). Martin (1960) identified M. arenaria, M. incognita acrita on tea plants. In a survey, Bride et al. (1976) reported an isolated case of M. acronea in cotton in the Shire valley in the southern region of Malawi. In Central, Western and Southern Tanzania, M. javanica and M. incognita were recognized as wide-spread species but M. javanica was most predominant (Whitehead, 1969). Swai (1981) summarized that seven species of root-knot nematodes viz., M. javanica, M. incognita, M. hapla, M. ethiopica, M. decalineata, M. africana and M. kikuyensis had been identified in Tanzania. Thomas and Taylor (1968) reported that in Eastern and Central Uganda, M. incognita and M. incognita acrita were equally common. However, Bafokuzara (1981) reported that M. javanica was the commonest species in Uganda. Way (1981) reported that M. javanica was the predominant root-knot nematode in Zimbabwe. M. incognita acrita, M. hapla and M. arenaria have also been recorded in the country (Martin, 1957). Studies in cooperation with IMP confirmed that M. javanica was more common species. M. incognita Race 3 was more prevalent than M. incognita Race 1. M. hapla was also present at high altitude (Richardson, 1978) (Table 6).

In the Region VI which comprised of 13 countries of Asia, distribution of M. incognita, M. javanica, M. arenaria and M. hapla were found to be quite extensive with the dominance of M. incognita (Davide, 1985) (Table 7). All the four races of M. incognita and Race 2 of M. arenaria were also found to be present in the region. In Bangladesh, M. graminicola was a common pest of rice in the shallow water situations. However,

Table 6. Species and races of root-knot nematodes (*Meloidogyne* species) recorded in the IMP Region V (East Africa).

Country	Species of *Meloidogyne*	Races of *M.incognita*	Races of *M.arenaria*	Reference
Kenya	*M.incognita*, *M.javanica*, *M.kikuyensis*	–	–	De Grisse (1960), Ngundo (1976)
Malawi	*M.incognita*, *M.javanica*, *M.arenaria*, *M.incognita acrita*, *M.acronea*	–	–	Martin (1960), Bridge *et al.* (1976) Saka (1981)
Tanzania	*M.incognita*, *M.javanica*, *M.hapla*, *M.ethiopica*, *M.decalineata*, *M.africana*, *M.kikuyensis*	–	–	Whitehead (1969) Swai (1981)
Uganda	*M.incognita*, *M.javanica*, *M.incognita acrita*	–	–	Thomas and Taylor (1968), Bafokuzara (1981)
Zimbabwe	*M.incognita*, *M.javanica*, *M.arenaria*, *M.hapla*, *M.incognita acrita*	1,3	–	Martin (1957), Richardson (1978), Way (1981)

– = Information about races of *M. incognita* or *M. arenaria* not available.

M. javanica was predominant species on vegetables (Chaudhury, 1981). *M. arenaria* and *M. incognita* Race 1 are also reported to occur in the country (Chaudhury, 1981). The root-knot nematodes identified to be present in Burma were *M. incognita*, *M. javanica*, and *M. graminicola* (Myint, 1981). *M. incognita* Race 1, *M. javanica* and *M. arenaria* Race 2 were identified in Fiji Island (Taylor *et al.*, 1982). In Indonesia, Widjaja (1981) reported that root-knot nematodes were common and very damaging to susceptible crops throughout the country. *M. incognita* Race 1 was most frequent species followed by *M. javanica* and *M. arenaria*. *M. javanica*, *M. incognita* Race 1 and *M. hapla* were detected on lettuce in Japan (Nishizawa, 1981, Inagaki, 1981). Four *Meloidogyne* species, *M. javanica*, *M. hapla*, *M. incognita* (Race 1 and 2) and *M. arenaria* (Race 2) were identified in Korea (Choi, 1981).

Razak (1981) identified root-knot nematodes in Malaysia, as *M. incognita* (Race 1, 3 and 4) and *M. javanica*. *M. javanica* and *M. incognita* were reported from Nepal (Hogger, 1981). *M. incognita*, *M. javanica*, *M. arenaria* and *M. hapla* were found in Pakistan associated with many cereal, fruit and vegetable plants (Maqbool and Saeed, 1981). Race 1 of *M. incognita* was also recognized in the country. In Philippines, Davide,(1981) examined 20 isolates and out of these, 8 were identified as *M. incognita*; 3 *M. javanica*; 7 *M. arenaria*; one *M. hapla*; and one isolated from a pine tree, *M. megatyla*. He also identified the presence of Race 1, 2 and 4 of *M. incognita* in the country.

M. incognita (Race 1 and 2), M. javanica, M. arenaria, M. hapla and M. brevicauda were identified in Sri Lanka (Sivapalan,1981). M. incognita Race 1, 2 and 3, M. javanica, M. hapla, M.arenaria and M. incognita acrita were found in Taiwan (Cheng and Tu,1980; Wang, 1978; Yang et al., 1977). M. incognita, however, was considered as the most common species (Tsai, 1981). Out of six species found present in Thailand, M. incognita was dominant species as it was found on various economically important crops. M. javanica and M. arenaria were less prevalent. M. graminicola, M. exigua and M. naasi were also recorded from rather specific areas. Race 1 and 2 of M. incognita were also identified in the country (Sontirat, 1981) (Table 7).

In the Region VII which consisted of 18 countries of Mediterranean region and the Middle East, the occurrence of root-knot nematodes were summarized by Ibrahim (1985). About eleven species of root-knot nematodes have been found in countries of this region (Table 8). In order of occurrence and importance, these species were M. javanica, M. incognita, M. thamesi, M. arenaria, M. hapla, M. naasi, M. artiellia, M. megadora, M. exigua, M. africana and M. incognita acrita. Generally M. javanica and M. incognita were the most wide-spread species, whereas others were limited in distribution. All the races of M. incognita and M. arenaria were recognized from the region (Ibrahim, 1985).

M. incognita Race 1 and M. javanica were reported from Algeria (Lamberti et al., 1975; Ibrahim, 1985). In Cyprus,

Table 7. Species and races of root-knot nematodes (*Meloidogyne* species) recorded in the IMP Region VI (Asia)

Country	Species of *Meloidogyne*	Races of *M. incognita*	Races of *M. arenaria*	Reference
Bangladesh	*M. incognita*, *M. javanica*, *M. arenaria* *M. graminicola*	1	–	Chaudhury (1981)
Burma	*M. incognita*, *M. javanica*, *M. gramincola*	–	–	Myint (1981)
Fiji Island	*M. incognita*, *M. javanica*, *M. arenaria*	1	2	Taylor *et al.* (1982)
Indonesia	*M. incognita*, *M. javanica*, *M. arenaria*	1	–	Widjaja (1981)
Japan	*M. incognita*, *M. javanica*, *M. hapla*	1	–	Inagaki (1981), Nishizava (1981)
Korea	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*	1,2	2	Choi (1981)
Malaysia	*M. incognita*, *M. javanica*	1,3,4	–	Razak (1981)
Nepal	*M. incognita*, *M. javanica*	–	–	Hogger (1981)
Pakistan	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*	1	–	Maqbool and Saeed (1981
Philippines	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. megatyla*	1,2,4	–	Davide (1981)
Sri Lanka	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. brevicauda*	1,2	–	Sivapalan (1981)
Taiwan	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. incognita acrita*	1,2,3	–	Cheng and Tu (1980), Wang (1978), Yang *et al.* (1977), Tsai (1981)
Thailand	*M. incognita*, *M. javanica*, *M. arenaria*, *M. graminicola*, *M. exigua*, *M. naasi*	1,2	–	Sontirat (1981)

– = Information about races of *M. incognita* or *M. arenaria* not available

M. javanica and *M. incognita* Race 1 and 2 were identified. *M. javanica* was predominant (Philis, 1979,1982). *M. javanica*, *M. incognita* and *M. arenaria* were found in Egypt. The first two species were widely distributed while *M. arenaria* was of limited occurrence (Ibrahim, 1982). Populations of *M. incognita* contained all the four races, Race 2, however, dominated. Race 1 of *M. arenaria* was also identified. Elgindi and Moussa (1979) studied the occurrence and distribution of *Meloidogyne* spp. in Egypt. Three species and one sub-species were identified as *M. arenaria*, *M. arenaria thamesi*, *M. incognita* and *M. javanica*. In Greece, *M. javanica*, *M. incognita* and *M. arenaria* were present throughout the costal region at elevation between 200 meters; *M. hapla* was found only in one location at an altitude above 450 meters (Pyrowolakis, 1975). Until, 1979, eight species had been reported from Greece (Koliopanos, 1979). In Iran, *M. javanica*, *M. incognita*, *M. arenaria* and *M. hapla* were present on a wide range of crop plants and weeds. Race 1 of *M. incognita* and Race 2 of *M. arenaria* were identified in the country (Abivardi, 1978; Abivardi *et al*., 1979; Mojtahadi, 1982). Stephan (1979) recognized *M. incognita*, *M. javanica* and *M. arenaria* in Iraq.

In Italy, *M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla* and *M. naasi* have been found attacking cultivated plants. *M. incognita* was most common species (Di Vito, 1979). Race 1 and Race 2 of *M. incognita* and *M. arenaria* Race 2 were determined in the country (Taylor and Sasser,1978; Di Vito and Greco, 1982).

Abu-Gharbieh (1979) reported the occurrence of *M. incognita* and *M. javanica* in Jordan. Presence of Race 1 of *M. incognita* was confirmed in the country (Abu-Gharbieh, 1982).

Khan and Dabaj (1980) reported the existence of *M. javanica* and *M. incognita* on vegetables crops grown in Tripoli region of Libya. Dabaj and Khan (1981) identified *M. javanica* and *M. incognita* as the species infecting tomato,potato in the Western region of Libya. *M. javanica* was found to be dominant species. Race 1 and 2 were identified in *M. incognita*. *M. hapla* was identified on eggplant (Khan and Siddiqui, 1986). In Morocco, *M. javanica*, *M. incognita*, *M. arenaria* and *M. hapla* were found as common species. Race 1, 2 and 4 of *M. incognita* and Race 1 and 2 of *M. arenaria* were identified in the country (Agadr *et al*., 1979; Janati *et al*., 1982; Ammati, 1982; Ibrahim, 1985). Santos and Abrantes (1979) reported that in Portugal, *M. incognita* Race 2 and 4, *M. arenaria* Race 2, *M. javanica* and *M. hapla* were present. Race 1 and Race 2 of *M. incognita* and *M. javanica* have been identified in Saudi Arabia (Eissa *et al*., 1979). Eissa *et al*. (1979) found *M. incognita* Race 2, as dominant root-knot nematode in the country.

In Spain, root-knot nematodes were identified as *M. javanica* and *M. incognita* (Race 1 and Race 3), with the former species predominating (Rodriguez *et al*., 1982; Ibrahim, 1985). Species of root-knot nematodes identified in Sudan were *M. javanica*, *M. incognita*, *M. arenaria*, *M. africana* and *M. megadora* (Decker *et al*., 1980; Yassin, 1978). In Syria,

Table 8. Species and races of root-knot nematodes (Meloidogyne species) in the IMP Region VII (Mediterranean and the Middle East).

Country	Species of Meloidogyne	Races of M.incognita	Races of M.arenaria	Reference
Algeria	M.incognita, M.javanica	1	-	Lamberti et al. (1975), Ibrahim (1985)
Cyprus	M.incognita, M.javanica	1,2	-	Philis (1979,1982)
Egypt	M.incognita, M.javanica, M.arenaria M.hapla, M.arenaria thamesi	1,2,3,4	1	Ibrahim (1982), Elgindi and Moussa(1979)
Greece	M.incognita, M.javanica, M.arenaria, M.hapla, M.exigua, M.acrita, M.thamesi M. artiellia	1	-	Koliopanos (1979) Pyrowolakis (1975)
Iran	M.incognita, M.javanica, M.arenaria, M.hapla	1	2	Abivardi (1978), Abivardi et al. (1979) Mojtahadi (1982)
Iraq	M.incognita, M.javanica, M.arenaria	-	-	Stephan (1979)
Italy	M.incognita, M.javanica, M.arenaria, M.hapla, M.naasi	1,2	2	Di Vito (1979), Taylor and Sasser (1978), Di Vito and Greco (1982)
Jordan	M.incognita, M.javanica	1	-	Abu-Gharbieh (1979, 1982)
Libya	M.incognita, M.javanica, M.hapla	1,2	-	Khan and Dabaj (1980), Dabaj and Khan (1981), Khan and Siddiqui, (1986)

Contd.

Table 8 (Continued).

Country	Species of *Meloidogyne*	Races of *M. incognita*	Races of *M. arenaria*	Reference
Morocco	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*	1,2,4	1,2	Agadr *et al.* (1979) Janati *et al.* (1982), Ammati (1982), Ibrahim (1985)
Portugal	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*	2,4	2	Santos and Abrantes (1979)
Saudi Arabia	*M. incognita*, *M. javanica*	1,2	–	Eissa *et al.* (1979)
Spain	*M. incognita*, *M. javanica*	1,3	–	Rodriguez *et al.* (1982), Ibrahim(1985
Sudan	*M. incognita*, *M. javanica*, *M. arenaria*, *M. afiricana*, *M. megadora*	–	–	Deckar *et al.* (1980) Yassin (1978)
Syria	*M. incognita*, *M. javanica*	1	–	Ibrahim (1985)
Tunisia	*M. incognita*, *M. javanica*	–	–	Moens and Alcha(1982,
Turkey	*M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. thamesi*, *M. incognita acrita*,	–	2	Yuksel (1979)
Yemen	*M. incognita*, *M. javanica*	1,3	–	Sikora (1978)

– = Information about races of *M. incognita* or *M. arenaria* not available.

M. javanica and *M. incognita* Race 1 were recognized (Ibrahim, 1985). *M. incognita* and *M. javanica* were reported in Tunisia (Moens and Alcha, 1982). Yuksel (1979) reported the occurrence of *M. incognita*, *M. javanica*, *M. incognita acrita*, *M. arenaria* (Race 2), *M. hapla* and *M. thamesi* in Turkey. From Yemen, Sikora (1978) reported the occurrence of *M. incognita* Race 1 and 3 and *M. javanica* on tomato, potato, pepper etc. (Table 8).

In the Region VIII, which included India only, very little work was done in collaboration with the IMP. Occurrence of several species of *Meloidogyne* on a variety of crops is on record in India (Table 9). Until, 1977, *M. incognita*, *M. javanica*, *M. hapla*, *M. indica*, *M. lucknowica*, *M. brevicauda*, *M. thamesi* and *M. graminicola* were known to exist in the country (Sasser, 1977). In 1984, eleven species of *Meloidogyne* viz., *M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. graminicola*, *M. lucknowica*, *M. acrita*, *M. brevicauda*, *M. africana*, *M. exigua* and *M. thamesi* were mentioned attacking a large number of host plants in India (Sitaramaiah, 1984). Since then, one more species, *M. graminis* was reported on wheat by Nayak *et al*. (1986). On differentiation of races in *M. incognita* and *M. arenaria* very little and sporadic work has been done (Krishnappa, 1985).

Out of 25 States in India, occurrence of root-knot nematode species are on record only from 18 States and their races from 6 States. In the State of Andhra Pradesh, Srinivasan and D'Souza (1965) recorded *M. exigua* on *Bidens pilosa*. Singh *et al*. (1979)

found in a survey that root-knot nematode was widely distributed on citrus roots. However, species was not identified by them. Krishnappa (1982) detected *M. incognita* Race 1 from the State. *M. incognita* was found on potato in Itanagar of Arunachal Pradesh (Mishra and Jayaprakash, 1980). *M. graminicola* was reported on rice from Assam (Roy, 1973). *M. incognita* was highly frequent in two jute growing districts of Assam (Bora and Phukan, 1986). Nirula and Kumar (1964, 1966) identified *M. incognita* and *M. javanica* infecting various kinds of plants in Northern India especially from Patna (Bihar) and Simla (Himachal Pradesh). *M. incognita*, *M. arenaria* and *M. acrita* were reported from the State of Bihar (Sinha *et al.*, 1977; Lal and Das, 1957, 1959; Nath *et al.*, 1976). Swarup (1962) reported the prevalence of *M. incogonita*, *M. incognita acrita* and *M. javanica* on vegetables in Delhi. Sethi *et al.* (1964) also reported the occurrence of *M. javanica* on *Impatiens balsamina* around Delhi. *M. thamesi* was recorded for the first time from India on *Eragrostis pilosa* (Sethi *et al.*, 1964). Chitwood and Toung (1960) reported *M. africana* from Delhi. *M. incognita* was found quite common species in Anand area of Gujarat State (Shah and Patel, 1979; Patel *et al.*, 1982). Bhatti *et al.* (1974) reported a few additional hosts of *M. javanica* from the State of Haryana. A few more host plants of *M. javanica* and *M. incognita* from Haryana were later added by Bhatti and Dahiya (1977). Raja and Gill (1982) identified the Race 1 and Race 2 of *M. incognita* from five populations of different localities. The occurrence of *M. incognita* and *M. javanica* was reported in Solan area of Himachal Pradesh

(Bharadwaj *et al*., 1972). While surveying the various orchards for plant parasitic nematodes in Himachal Pradesh, Chandel and Kashyap (1986) found that *Meloidogyne* spp. showed highest frequency in the State. *M. hapla* was reported from the State by Gill (1975).

Krishnappa (1982) and Krishnappa and Setty (1983) found the existence of *M. incognita* in Karnataka. They also detected Race 1 Race 2 and Race 3 existing in the State. Singh and Krishnaprasad (1986) reported *M. incognita* on potato from the State. Nursuries of strawberries were found infected with *Meloidogyne* spp.in Shalimar campus of Kashmir State (Waliullah and Kaul, 1986). The occurrence of *Meloidogyne* spp. on turmeric from Kerala was reported by Ayyar (1926). *M. incognita* and *M. javanica* were found major nematode species distributed in the State on many crops (Nadakal and Thomas, 1964; Nair *et al*., 1969; Raveendran and Nadakal, 1975; Ramana and Mohandas, 1987). Krishnappa (1982) detected *M. incognita* Race 1 on groundnut from Madhya Pradesh. Shukla *et al*. (1981) recorded *M. incognita* on ornamental plants at Nagpur in Maharastra State. *M.graminicola* on rice was reported from Orissa (Rao *et al*., 1971). Routray and Das (1982) found the existence of Race 1 and Race 2 of *M.incognita* in and around Bhubaneswar, Orissa. Ray and Das (1985) reported *M. incognita* on medicinal plants from the State, while Nayak *et al*. (1986) recorded the occurrence of *M. graminis* on wheat, for the first time in India. From Rajasthan State, *M. incognita* and *M. javanica* were found associated with many kinds of plants

(Mathur *et al*., 1969; Handa *et al*., 1971; Soni and Nama, 1982; Trivedi *et al*., 1986). Siddiqui *et al*. (1986) collected the samples for plant parasitic nematodes in and around Udaipur. They found *Meloidogyne* spp. quite common in the samples. Parihar and Yadav (1986) collected four populations of *M. incognita* from Jaipur, Jodhpur, Sriganganagar and Udaipur of Rajasthan State. They tested on host differential test plants and suggested the presence of races in the populations. But races were, however, not designated by them. *M. incognita* Race 1, *M. javanica* and *M. arenaria* have been recorded widely prevalent in Tamil Nadu State (Krishnamurthy and Elias, 1967, 1968; Swamy and Govindo, 1966; Jayaraman *et al*., 1975; Krishnappa, 1982; Sivagami and Rajendran, 1987). *M. hapla* and *M. brevicauda* were also reported from the State (Seshadri and Kumaraswami, 1963).

In the State of Uttar Pradesh, in order of occurrence of species of root-knot nematodes, *M. incognita*, *M. javanica* followed by *M. arenaria* were reported on several host plants (Verma and Singh, 1983; Sitaramaiah and Vishawakarama, 1978; Mathur and Varaprasad, 1978; Khan *et al*., 1984; Khan and Khan, 1985; Haider and Khan, 1986; Prakash, 1983; Verma, 1987). Singh (1969) described *M. lucknowica* on *Luffa cylindrica* from the State. The root-knot nematodes, *M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. acrita* and *M. graminicola* have been reported from West Bengal on a number of host plants (Dutt and Panda, 1968; Dutt and Saha, 1973; Samad, 1960; Sen and Dasgupta, 1975,1977; Pal and Jayaprakash, 1983; Singh and Khera, 1984) (Table 9).

Table 9. Species and races of root-knot nematodes (*Meloidogyne* species) recorded in the IMP Region VIII (India).

State	Species of *Meloidogyne*	Races of *M. incognita*	Races of *M. arenaria*	Reference
Andhra Pradesh	*M. incognita*, *M. exigua*	1	-	Singh *et al.* (1979), Krishnappa (1982), Srinivasan and D'Souza (1965)
Arunachal Pradesh	*M. incognita*	-	-	Mishra and Jayaprakash (1980)
Assam	*M. incognita*, *M. graminicola*	-	-	Roy (1973), Bora and Phukan (1986)
Bihar	*M. incognita*, *M. javanica*, *M. arenaria*, *M. acrita*	-	-	Nirula and Kumar (1964, 1966), Sinha *et al.* (1977), Nath *et al.* (1976), Lal and Das (1957, 1959)
Delhi	*M. incognita*, *M. javanica*, *M. arenaria*, *M. thamesi*, *M. incognita acrita*, *M. africana*	-	-	Swarup (1962), Sethi *et al.* (1964), Chitwood and Toung (1960)
Gujarat	*M. incognita*	-	-	Shah and Patel (1979), Patel *et al.* (1982)
Haryana	*M. incognita*, *M. javanica*	1,2	-	Bhatti *et al.* (1974) Bhatti and Dahiya (1977) Raja and Gill (1982)
Himachal Pradesh	*M. incognita*, *M. javanica*, *M. hapla*	-	-	Bharadwaj *et al.* (1972) Chandel and Kashyap (1986), Nirula (1964, 1966), Gill (1975)

Contd.

Table 9 (Continued).

State	Species of *Meloidogyne*	Races of *M. incognita*	Races of *M. arenaria*	Reference
Karnataka	*M. incognita*	1,2,3	-	Krishnappa (1982), Krishnappa and Setty (1983), Singh and Krishnaprasad (1986)
Kashmir	*Meloidogyne* spp.	-	-	Waliullah and Kaul (1986)
Kerala	*M. incognita*, *M. javanica*	-	-	Ayyar (1926), Nadakal and Thomas (1964), Raveendran and Nadakal (1975), Ramana and Mohandas (1987), Nair *et al.* (1969)
Madhya Pradesh	*M. incognita*	1	-	Krishnappa (1982)
Maharastra	*M. incognita*	-	-	Shukla *et al.* (1981)
Orissa	*M. incognita*, *M. graminicola*, *M. graminis*	1,2	-	Routray and Das (1982), Ray and Das (1985), Rao *et al.* (1971), Nayak *et al.* (1986)
Rajasthan	*M. incognita*, *M. javanica*	-	-	Mathur *et al.* (1969), Handa *et al.* (1971), Soni and Nama (1982), Trivedi *et al.* (1986) Siddiqui *et al.* (1986) Parihar and Yadav (1986)

Contd.

Table 9 (Continued).

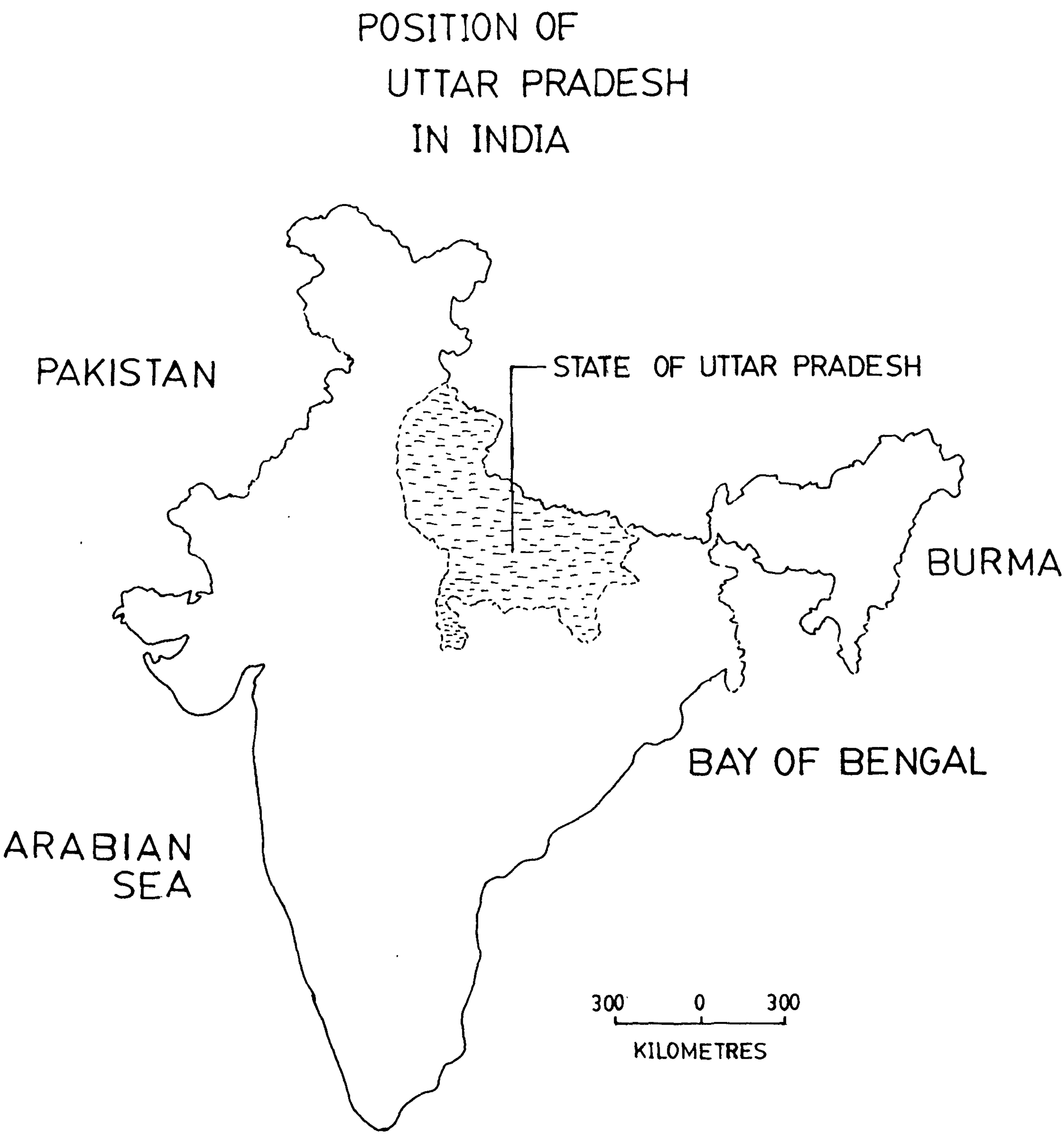
State	Species of *Meloidogyne*	Races of *M. incognita*	Races of *M. arenaria*	Reference
Tamil Nadu	*M. incognita*, *M. javanica*, *M. arenaria* *M. hapla*, *M. brevicauda*	1	–	Krishnamurthy and Elias (1967,1968), Swamy and Govindo (1966), Jayaraman *et al.* (1975), Krishnappa (1982), Sivagami and Rajendran (1987), Seshadri and Kumaraswami (1963)
Uttar Pradesh	*M. incognita*, *M. javanica*, *M. arenaria*, *M. lucknowica*	–	–	Verma and Singh (1983), Sitaramaiah and Vishwa-karma (1978), Mathur and Varaprasad (1978) Khan *et al.* (1984), Khan and Khan (1985), Haider and Khan (1986) Prakash (1983), Singh (1969), Verma (1987)
West Bengal	*M. incognita*, *M. javanica*, *M. arenaria* *M. graminicola*, *M. hapla*, *M. acrita*	–	–	Sen and Dasgupta (1975, 1977), Pal and Jayaprakash (1983), Singh and Khera (1984), Dutt and Panda (1968), Dutt and Saha (1973), Samad (1960)

– = Information about races of *M. incognita* or *M. arenaria* not available.

Since the establishment of a pioneer and active centre of research in Plant Nematology in 1962 at the Aligarh Muslim University, Aligarh located in the Western part of Uttar Pradesh substantial work has been done on various aspects of root-knot nematode problems of vegetables. A perusal of literature on researches emanating from Aligarh, however, gives an impression that *M. incognita* is the only root-knot nematode species causing the disease on crops in and around Aligarh as well as in the areas covered during all these years. Apparently, it seems that no attempt was made to ascertain the identity of species of *Meloidogyne* existing in and around Aligarh on vegetables in cultivated fields. Recognition of *M. incognita* perhaps observed preliminary as the causal organism of root-knot disease on certain crops seemingly became a traditional causal organism in subsequent studies on root-knot problems. Recent studies of Khan *et al.* (1984), Khan and Khan (1985) and Haider and Khan (1986) however, recognised the existence of *M. incognita*, *M. javanica* and *M. arenaria* in Aligarh area. Occurrence of these species was expected in the area in view of their ecological requirements. In view of greater recognition of the importance of root-knot nematodes than earlier through the studies of IMP and lack of pursuance of studies in relation to the incidence and intensity of the disease in different States of India, identity of species and races of root-knot nematodes and their pattern of distribution and relative dominance in various agro-climatic zones of the country, the present studies were undertaken. The above aspects have been studied in 8 districts of the State of Uttar Pradesh, selecting vegetables as host crops mainly because they are commonly grown in the area and are most preferred group of host crops for root-knot nematodes.

Geography of India

India is the seventh biggest country in the world and second in population. The shape of India is like a triangle with its base resting on the Himalayan-mountain in the north and its apex running far into the ocean in the south. At the southern extremity, the triangle tapers with a bear shaped curve to a point called Cape Comorin now known Kanya Kumari. The total land area is 32,80,483 km^2. India lies entirely to the north of the equator. From south to north including Kashmir, it stretches from $8^o4'$ to $37^o6'$ north latitude, with the Tropic of cancer cutting it roughly into two halves. West to east, it stretches from about $68^o7'$ to $97^o25'$ east longitude. The country is bound by China and Nepal in north, Bangaladesh and Burma in east. Pakistan in west and Ocean in south. Indian mainland comprises three well defined natural regions (1) The Mountain Wall, (2) The Indo-Gangetic Plain, and (3) The Southern Peninsula. The Indo-Gangetic Plain, 2,214 km long and 241 to 321 km broad, is formed by the basins of three distinct river systems, the Indus, the Ganga and the Brahamputra. It is one of the world's greatest stretches of flat alluvium and also one of the most densely populated areas on earth.


POSITION OF
UTTAR PRADESH
IN INDIA
PAKISTAN
STATE OF UTTAR PRADESH
BURMA
BAY OF BENGAL
ARABIAN
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300 0 300
KILOMETRES

Fig.1

Agriculture is under practice since Indus Vally civilization about 4500 years ago. Now India is a predominantly, an agricultural country. About half of the country's national income is derived from agricultural and allied activities which absorb nearly 70 per cent of its working force. The most important crops are rice, wheat, millets, sugarcane, cotton, pulses, tea, coffee, oilseeds, tobacco, jute and vegetables (Mohan and Aggarwal, 1985).

The State of Uttar Pradesh

At present, India has 25 States. Uttar Pradesh, the most populous (population 110,885,874) State of India, covers an area of 294,364 km^2. The State is fourth largest in terms of area and ranks first in terms of population. It is a land locked State, situated between $25^{o}18'$ and $31^{o}18$ N, and $77^{o}10$ and $89^{o}39$E. Agriculture in this region was started by the Aryans. Aryans came to India from Middle Asia in about 1500 BC and they established at the banks of Ganga and Yamuna rivers. But agriculture started only after expansion between 1200-800 BC on the length of rivers. The Yamuna-Ganga plain is supposed to be one of the most fertile area since the Aryan civilization. The land is built-up of alluvial soil. It is traversed by a number of rivers which almost run parallel to each other. Since the land is fertile and weather conditions are moderate, it is highly suitable for agriculture. The principal crops are wheat, rice, barley, maize, bajra, gram, pea, cotton, linseed, groundnut, sugarcane, sesamum, rapeseed,

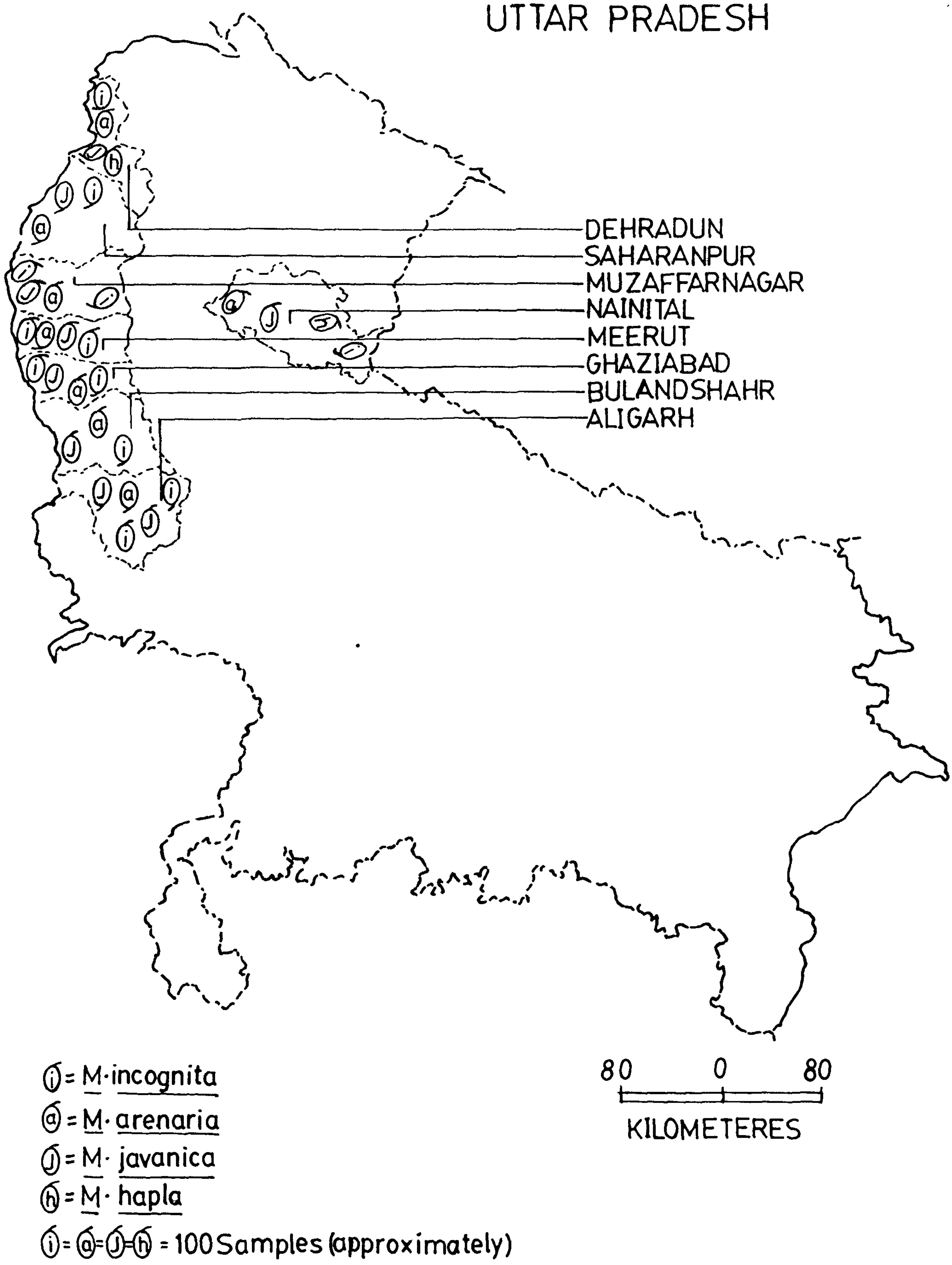


Fig. 2: Districts of Uttar Pradesh included in the survey.

Table 10. Meteorological data and topography

District	Location	Altitude above sea level (m)	Area (Km^2)	Temperature (C^o) Range Min.	Temperature (C^o) Range Max.	Rainfall Average (mm)
Aligarh	27°29' and 28°11'N 77°29' and 78°38'E	192	5025	9.7 - 28.0 (January)*	22.5 - 47.0 (June)**	594.1
Bulandshahr	28°4'3" and 28°0'28" N 77°0'18" and 78°0'28" E	218.1	4895	8.0 - 21.0 (January)	27.0 - 41.0 (June)	814.0
Ghaziabad	28°40'N 77°26'E	211.5	728	8.0 - 21.0 (January)	26.0 - 42.0 (June)	814.0
Meerut	29°1'N 77°43'E	231.6	5944	8.1 - 20.9 (January)	25.3 - 46.0 (June)	814.0
Muzaffarnagar	29°11'30" and 29°45'15" N 77°3'45" and 78°7'E	237-247	4245	7.0 - 20.0 (January)	24.0 - 44.0 (June)	814.0
Saharanpur	29°34' and 30°24'N 77°7' and 78°12'E	875-942	5526	6.6 - 20.1 (January)	25.0 - 39.0 (June)	2183.5
Dehradun	29°57' and 31°2'N 77°35' and 78°20'E	1967.40- 3022.50	3088	(-)6.0- 6.1 (Dec.-Jan.)	19.1 - 36.2 (June)	2183.5
Nainital	28°51' and 29°37'N 78°43' and 80° 5'E	2455.80- 2570.40	6792	(-)7.5- 5.0 (Dec.-Jan.)	17.5 - 30.0 (June)	2583.3

Note : The soil in the area is alluvial type.

* = Months in parentheses in this column indicate coldest month in the district.

** = Months in parentheses in this column indicate hottest month in the district.

mustard, tobacco and vegetables. Forests cover 17.23 per cent of the area of the State (Khan, 1969).

Vegetables are important crops, mainly grown nearby the villages or around the city. Tomato, eggplant, pepper, potato, okra, cabbage, cauliflower, cucumber, pumpkins, radish, beans, spinach, carrot and onions are major vegetable crops grown in the State. At present there are 59 districts in Uttar Pradesh. Out of 59 districts, 8 districts (6 of Western Upper Gangetic Plain and 2 of Northern Hilly Regions) have been selected for survey to determine incidence and intensity of the disease, identity of species and races of Meloidogyne and their pattern of distribution on some commonly grown gegetable crops in the districts. The districts included in the survey are situated between Ganga and Yamuna rivers called Doab. The districts, Aligarh, Bulandshahr, Ghaziabad, Meerut, Muzaffarnagar, Saharanpur, and Dehradun lies at south-north direction and Nainital at north-east direction of the State (Figs. 1,2).

The 8 districts included in the survey cover the total area about 36,243 km^2. out of 294,364 km^2. (12.31%) of Uttar Pradesh and 1.104% of India. The meteorological data and topography of the districts under study are given in Table 10. January is the coldest and June is the hottest month of the year in the area.

MATERIALS AND METHODS

The different materials used and methods employed to investigate the proposed aspects are generalized as follows:

1. Survey and collection:

Surveys were conducted in localities of extensive vegetable cultivation in six district of Western Upper Gangetic Plain (Aligarh, Bulandshahr, Ghaziabad, Meerut, Muzaffarnagar and Saharanpur) and two districts of Northern Hilly Region (Dehradun and Nainital) of Uttar Pradesh State in India (Fig.2, Table 10) to assess the incidence and intensity of root-knot disease on vegetable crops, to establish the identity of species and races of root-knot nematodes and to understand their pattern of distribution. Following seven vegetables commonly grown in the area were included in the surveys.

1. Eggplant (*Solanum melongena* L.)
2. Tomato (*Lycopersicon esculentum* Mill.)
3. Pepper (*Capsicum annuum* L.)
4. Okra (*Abelmoschus esculentus* (L.) Moen.)
5. Cucumber (*Cucumis sativus* L.)
6. Cauliflower (*Brassica oleracea* L. var. *botrytis*)
7. Cabbage (*Brassica oleracea* L. var. *capitata*)

Surveys were conducted from March to May for eggplant, pepper, okra, cucumber and from September to November for tomato, cauliflower, and cabbage in each year from 1984 to 1987. In Western Upper Gangetic Plain districts, mostly outdoor fields of farmers were included. However, in some localities of Northern Hilly Region districts, vegetables grown in kitchen gardens were also observed. Five to ten root samples of the above mentioned vegetable crops were collected at random from each of the available cultivation units in the locality under survey in polythene bags. Samples were properly labelled and slightly moistened when necessary and brought to laboratary for further examination. Root samples were thoroughly washed under tap water and were examined for the presence of galls. Number of galls per root system was counted. Roots were immersed in an aqueous solution of Phloxin B (0.15 g/lit. tap water) for 15 minutes to stain the eggmasses. Eggmasses per root system were then counted.

For measuring the intensity of the disease, gall index (GI) and eggmass index (EMI) ratings were done according to the following scale (Taylor and Sasser,1978).

0=0, 1=1-2, 2=3-10, 3=11-30, 4=31-100 and 5=greater than 100 galls or eggmasses per root system.

Based on gall index and eggmass index disease intensity grades were made as follows: 0=Disease free, 1=very mild, 2=mild, 3=moderate, 4=severe, 5=very severe.

To assess the incidence of the root-knot disease in different localities of the district in the area under survey on included vegetables, frequency of occurrence of the disease was calculated in two ways: (a) on the basis of infestation of cultivation unit in the locality and (b) on the basis of infected root samples collected from a locality.

The frequency of occurrence of the disease in a locality was calculated by the following formula:

$$\text{Frequency (\%)} = \frac{\text{Number of cultivation units from a locality in which infection occurred}}{\text{Total number of cultivation units from the locality surveyed}} \times 100$$

The frequency of occurrence of the disease on the basis of infected root samples was calculated as follows:

$$\text{Frequency (\%)} = \frac{\text{Number of infected root samples collected from a locality}}{\text{Total number of root samples collected from the locality}} \times 100$$

Similarly, frequency of occurrence of the disease on different vegetables in a district was calculated in both ways: (a) on the basis of infested cultivation units of a vegetable crop in the district and (b) on the basis of infected root samples of a vegetable crop collected from the district.

Frequency of occurrence (%) of the disease on different vegetable crops on the basis of infested cultivation units was calculated as follows:

$$\text{Frequency (\%)} = \frac{\text{Number of cultivation units of a vegetable crop in the district in which infection occurred}}{\text{Total number of cultivation units of the vegetable surveyed in the district}} \times 100$$

Frequency of occurrence of the disease on different vegetable crops on the basis of infected root samples was calculated as follows:

$$\text{Frequency (\%)} = \frac{\text{Number of infected root samples of a vegetable collected from the district}}{\text{Total number of root samples of the vegetable collected from the district}} \times 100$$

2. Preliminary identification of species :

Samples collected during the survey were processed for preliminary identification of species of root-knot nematodes. Ten to twenty perineal patterns were prepared from each of the root samples and their characteristics were microscopically examined for identification of the species (Eisenback *et al.*,1981). Root-knot nematodes from infected samples were maintained under glasshouse conditions.

3. Maintenance of root-knot nematodes under controlled conditions :

Root samples infected with root-knot nematodes were maintained on susceptible cultivars of eggplant cv. Pusa Kranti in summer and tomato cv. Pusa Ruby in winter (both cultivars were found most suitable hosts for maintenance of *Meloidogyne* spp.) in glasshouse by inoculating the seedlings grown in pots containing autoclaved soil, with chopped infected roots or eggmasses, collected from the fields. The inocula were further cultured in pure form.

4. Pure culturing :

In order to make pure culture of the field populations directly or maintained in glasshouse, single eggmass inoculations were made. Single mature eggmass was inoculated in pots around the roots of the susceptible host for each collection separately. If more than one species were found on same root sample, single eggmass for each of the species was collected and inoculated separately and females producing the same eggmasses were dissected out and identified. Sub-culturing was done after two months by inoculating new plants as mentioned in 3 with at least 15 eggmasses, each obtained from the pure culture in order to maintain sufficient inoculum for further studies.

5. Preparation of inoculum :

For differentiating the species and the races by differential host test and for other experiments inoculation was made in the form of freshly hatched second stage juveniles (J_2). Second stage juveniles were obtained by incubating eggmasses, collected from plant roots maintaining pure population, in sterilized water, incubated at 20°C. After 72 h of incubation, number of hatched juveniles (J_2)/ml was standardized by counting the ten 1 ml samples and the average number was used to represent the number of J_2/ml.

6. Identification of species and races of root-knot nematodes :

Parineal pattern method and differential host test were employed for the identification of species and races of root-knot nematodes. Emphasis was given on the following species of *Meloidogyne* :

1. *Meloidogyne incognita*
2. *Meloidogyne javanica*
3. *Meloidogyne arenaria*
4. *Meloidogyne hapla*

a. *Perineal pattern method*

To identify the species of *Meloidogyne* maintained in glasshouse, mature females were dissected out from large galls on the roots of susceptible host. Perineal patterns were prepared and examined as mentioned in 2.

b. *Differential host test*

North Carolina differential host tests (Taylor and Sasser, 1978) were conducted to determine the species and races of *Meloidogyne* collected during the surveys and maintained in the glasshouse. Seedlings of tomato cv. Rutgers, cotton cv. Deltapine 16, tobacco cv. NC 95, pepper cv. California Wonder, peanut cv. Florrunner and watermelon cv. Charleston Grey were grown in 15 cm clay pots filled with sandy loam soil with three replications. Two additional replicates of tomato were included to determine the time of termination of the test. Plants were inoculated at the rate of 5,000 freshly hatched second stage juveniles (J_2)/pot. Juveniles were pipetted into 4-5 holes made in the soil around each seedling. Pots were placed on benches in the glasshouse at temperature $25 \pm 2^{o}C$. Sixty days after inoculation, experiment was terminated, the plants were uprooted and washed thoroughly with tap water and examined for the presence of galls. Roots with very light infection were stained with Phloxin B to determine the number of eggmasses. Galls and eggmasses were counted and rated according to the scales mentioned under the survey.

After rating the root system, results were compared with the differential host test reaction chart (Table 11) (Taylor and Sasser, 1978). This distinguished the four species of Meloidogyne viz., M. incognita, M. javanica, M. arenaria and M. hapla. The identification of species done on the basis of differential host test were compared with identifications made earlier by perineal pattern method for confirmation of their identity. The race differentiation was based on the results of differential host test and its comparison with differential host test reaction chart (Table 11).

7. Frequency of occurrence of species :

After identification of the species present in the samples, frequency of different species of Meloidogyne in single populations as well in mixed populations of different species combinations occuring in a locality was calculated as follows:

Table 11. North Carolina Differential Host Test Reaction Chart.

Meloidogyne species and races		Cotton cv. Deltapine 16	Tobacco cv. NC 95	Pepper cv. California Wonder	Watermelon cv. Charleston Grey	Peanut cv. Florrunner	Tomato cv. Rutgers
M. incognita							
	Race 1	– [1]	–	+	+	–	+
	Race 2	–	+	+	+	–	+
	Race 3	+	–	+	+	–	+
	Race 4	+	+	+	+	–	+
M. javanica		–	+	– (+)[2]	+	– (+)	+
M. arenaria							
	Race 1	–	+	+	+	+	+
	Race 2	–	+	+	+	–	+
M. hapla		–	+	+	–	+	+

1 Box indicates key differential host plants.

2 Parentheses indicate that a small proportion of the populations attack that host.

For single species population -

$$\text{Frequency (\%)} = \frac{\text{Number of infected root samples with single species population in a locality}}{\text{Total number of infected root samples collected from the locality}} \times 100$$

For mixed species populations of different species combination

$$\text{Frequency (\%)} = \frac{\text{Number of infected root samples with mixed species population of a particular species combination in a locality}}{\text{Total number of infected root samples collected from the locality}} \times 100$$

For comparative assessment of dominance of a species in different localities in a district either in single or mixed populations, frequency of different species in single as well as in mixed populations of different species combinations among different localities of the district were calculated as follows:

For single species population -

$$\text{Frequency (\%)} = \frac{\text{Number of infected root samples with single species in a locality of the district}}{\text{Total number of infected root samples collected from all the localities of a district}} \times 100$$

For mixed species populations of different species combinations -

$$\text{Frequency (\%)} = \frac{\text{Number of infected root samples with mixed species population of a particular species combination in a locality of the district}}{\text{Total number of infected root samples collected from all the localities of a district}} \times 100$$

Thenafter, frequency of occurrence of different species of *Meloidogyne* recorded in different localities of the district based on total infected root samples regardless of single or mixed species population, was calculated as follows:

$$\text{Frequency (\%)} = \frac{\text{Number of root samples infected with the species}}{\text{Total number of infected root samples}} \times 100$$

Similarly, frequency of occurrence of a recorded species of *Meloidogyne* among different localities of the district irrespective of single or mixed species populations, was calculated as follows:

$$\text{Frequency (\%)} = \frac{\text{Number of root samples infected with the species in a locality of the district}}{\text{Total number of infected root samples collected from all the localities of the district}} \times 100$$

8. Frequency of occurrence of races :

Frequency of occurrence of different races of *M. incognita* and *M. arenaria* identified in different localities of the district based on total infected root samples of the respective species, was calculated as follows:

$$\text{Frequency (\%)} = \frac{\text{Number of root samples infected with the race of the species in a locality}}{\text{Total number of infected root samples with the species in the locality}} \times 100$$

Frequency of occurrence of a identified race of *Meloidogyne incognita* and *M. arenaria* among different localities of the district was calculated as follows:

$$\text{Frequency (\%)} = \frac{\text{Number of root samples infected with the race of the species in a locality of the district}}{\text{Total number of infected root samples with the race collected from all the localities of the district}} \times 100$$

9. <u>Overall assessment</u> :

For overall assessment of the incidence of the root-knot disease in the area under survey on included vegetables, frequency of occurrence (%) of the disease in different districts was also calculated accordingly on the basis of infestation of cultivation units in the district as well as on the basis of infected root samples collected from a district (Table 52).

Similarly, frequency of occurrence (%) of the disease on different vegetables in the area, was calculated on the basis of infested cultivation units of a vegetable crop in the area. Based on root samples, frequency of occurrence (%) of the disease on different vegetables in the whole area was also calculated (Table 53).

Intensity of the disease in different districts and on different vegetables was assessed based on average GI/EMI (Table 52,53).

Frequency of occurrence (%) of the species of <u>Meloidogyne</u> in single and mixed populations (with different combinations) was also calculated for the each district. Thenafter, frequency of occurrence (%) of the species in each district was calculated based on total infected root samples (Table 54,55). Frequency of occurrence (%) of a species among districts either in single or mixed populations as well as frequency of occurrence (%) of a species among the districts based on total infected root samples were also calculated (Table 54 and 55).

Frequency of occurrence (%) of races of *M. incognita* and *M. arenaria* was calculated for different districts and of a race among the districts of the area to assess their comparative dominance (Table 56).

RESULTS

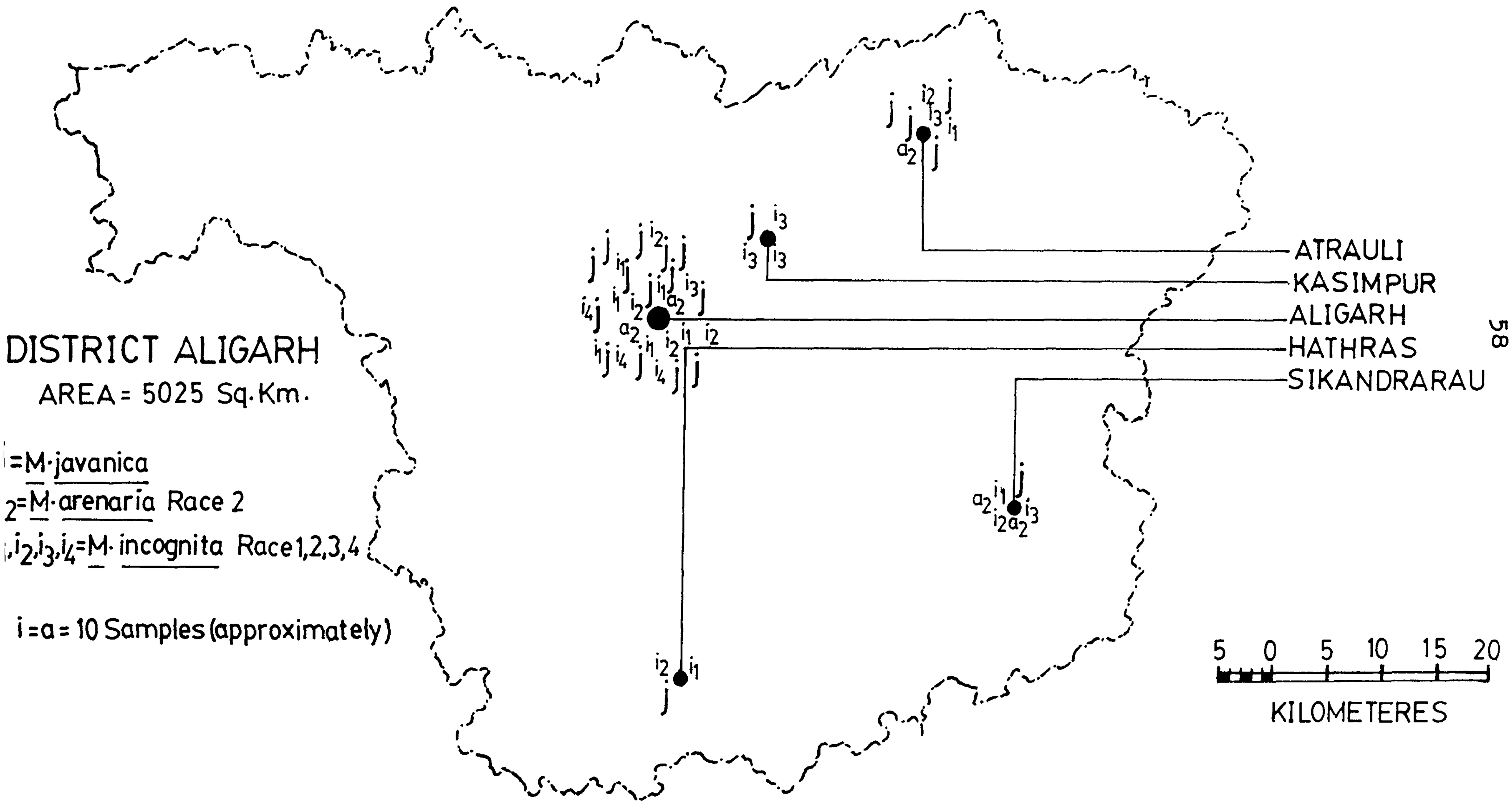
Surveys were conducted in different localities of 8 districts in the Western region of the State of Uttar Pradesh to assess the incidence and intensity of root-knot disease on vegetable crops, to identify the species and races of root-knot nematodes (*Meloidogyne* species) and to understand their pattern of distribution in the region. Emphasis were given to the four major species of *Meloidogyne* viz., *Meloidogyne incognita*, *M. javanica*, *M. arenaria* and *M. hapla* and their races infecting vegetables in the region.

The details of incidence and intensity of root-knot disease on vegetables and identity of species and races of root-knot nematodes and their frequency of occurrence in the localities surveyed are given below separately for each district.

1. ALIGARH

Incidence and intensity of the disease :

Five localities in the district viz., Aligarh city area, Atrauli, Kasimpur, Hathras and Sikandrarau (Fig.3) were surveyed. Fifty to hundred per cent vegetable fields were infested with root-knot nematodes in the localities. Of the five localities, incidence of the disease was highest in Atrauli (100%) followed by Aligarh city area (83.78%). In other three localities, incidence was 50% or above (Table 12).



3: Distribution of root-knot nematodes and their races in district Aligarh.

When frequency of occurrence of the disease was calculated on root sample basis, it emerged that 51.34% root samples from Aligarh city area and 51.28% from Atrauli were infected. These were followed by Kasimpur where frequency of occurrence of the disease in root samples was 45%. The frequency of the disease in root samples from Sikandrarau and Hathras was comparatively low (Table 12).

Gall index (GI) in infected root samples ranged from 2 to 5 and eggmass index (EMI) from 0 to 5 in the localities of the district. In some root samples from Hathras, there was no eggmass production but in other samples, EMI was 5. Highest intensity based on GI and EMI was observed in Kasimpur. The intensity was mild to very severe in Aligarh city area and Sikandrarau and very mild to very severe in Atrauli. Highest intensity range (severe to very severe) based on gall index was in Kasimpur. It was moderate to very severe in Hathras. However, intensity range (mild to very severe) was equal in rest of the localities (Table 12).

Among the crop fields of vegetables included in the survey, the incidence was highest in cucumber fields (100%) followed by the fields of eggplant (88.23%) and okra (85.71%). In tomato and pepper fields, it was above 50%. In cauliflower fields, incidence was slightly lower than in tomato and pepper fields. Cabbage fields surveyed were found free from infection (Table 13). The frequency of occurrence of the disease in root

Table 12. Incidence and intensity of root-knot nematodes on vegetables crops in different localities of Aligarh district.

Locality	Incidence						Intensity
	No.of cultivation units			No.of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Aligarh city area	37	31	83.78	372	191	51.34	2-5/2-5
Atrauli	8	8	100.00	78	40	51.28	2-5/1-5
Kasimpur	6	3	50.00	60	27	45.00	4-5/3-5
Hathras	9	6	66.66	100	11	11.00	3-5/0-5
Sikandrarau	8	4	50.00	100	24	24.00	2-5/2-5

GI = Gall index; EMI = Eggmass index

samples of vegetables was highest for cucumber (62.22%) closely followed by eggplant (60%) and okra (52.94%). On other vegetables, it was slightly below 25% (Table 13).

Intensity of the disease on different vegetables showed variations. Highest intensity range (severe to very severe) was found on cauliflower as GI/EMI were 4-5/4-5. Intensity range was at par on tomato and cucumber; GI/EMI being 3-5/3-5. On eggplant, pepper and okra roots, the GI/EMI were 2-5/0-5, the intensity range being nil to very severe. On some pepper roots no eggmass development was found at the time of survey (Table 13).

<u>Identity and frequency of root-knot nematode species</u> :

a. <u>Identity of the species</u> :-

Three species of *Meloidogyne* viz., *M. incognita*, *M. javanica*, and *M. arenaria* were found in the localities of the district (Fig.3, Table 14). Single populations of *M. incognita* or *M. javanica* and mixed populations of *M. incognita* and *M. javanica*, or *M. incognita* and *M. arenaria* or *M. javanica* and *M. arenaria* or of all the three species were recorded. *M. incognita* and *M. javanica* were present either singly or concomitantly in all the localities. *M. arenaria* was, however, found only in Aligarh city area, Atrauli and Sikandrarau in mixed populations either with *M. javanica* or *M. incognita* or with both the species (Table 14).

Table 13. Incidence and intensity of root-knot nematodes on different vegetable crops in Aligarh district.

Crop	Incidence						Intensity
	No. of cultivation units			No. of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Eggplant	17	15	88.23	175	105	60.00	2-5/2-5
Tomato	16	11	56.25	167	50	29.94	3-5/3-5
Pepper	13	9	53.84	140	34	24.28	2-5/0-5
Okra	7	6	85.71	68	36	52.94	2-5/1-5
Cucumber	9	9	100.00	90	56	62.22	3-5/3-5
Cauliflower	5	2	40.00	50	12	24.00	4-5/4-5
Cabbage	1	-	-	20	-	-	-

GI = Gall index; EMI = Eggmass index

b. Frequency of the species in single and mixed populations :-

In single population, frequency of *M. javanica* was slighly higher than *M. incognita* in Aligarh city area but they were equally frequent in Hathras. In Atrauli, *M. incognita* was not found in single population. On the other hand, *M. javanica* was not encountered in single population in Kasimpur and Sikandrarau. When the frequencies of a species in single population in different localities were accounted, *M. incognita* was found most frequent in Aligarh city area followed by in Kasimpur. Its frequency in Hathras and Sikandrarau was relatively poor. *M. javanica* was most frequent in Aligarh city area followed by Atrauli and Hathras (Table 14).

The frequency of mixed populations of *M. incognita* and *M. javanica* was greater in all the localities than mixed populations of *M. incognita* and *M. arenaria* or *M. javanica* and *M. arenaria* or *M. incognita*, *M. jaganica* and *M. arenaria* except in Sikandrarau, where frequency of mixed populations of *M. incognita* and *M. arenaria* was much greater than of *M. incognita* and *M. javanica*. Among the localities, frequency of mixed populations of *M. incognita* and *M. javanica* was highest in Aligarh city area (Table 14).

c. Frequency of the species in total infected samples :-

Frequency of occurrence of the species in total infected root samples regardless of single or mixed populations is given

Table 14. Frequency of occurrence of the species (%) of root-knot nematodes in single and mixed populations on vegetable crops in different localities of Aligarh district.

Locality	Frequency of species						
	Single population			Mixed population			
	Mi	Mj	Ma	Mi+Mj	Mi+Ma	Mj+Ma	Mi+Mj+Ma
Aligarh city area	20.41* (60.93)**	27.74 (76.81)	-	41.36 (66.38)	6.28 (41.85)	-	4.18 (100.00)
Atrauli	-	35.00 (20.28)	-	52.50 (17.64)	-	12.50 (100.00)	-
Kasimpur	62.96 (26.56)	-	-	37.03 (8.40)	-	-	-
Hathras	18.18 (3.12)	18.18 (2.89)	-	63.63 (5.88)	-	-	-
Sikandrarau	25.00 (9.37)	-	-	8.33 (1.68)	66.66 (57.14)	-	-

* Values in rows represent frequency (%) of the species in the same locality.

**Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = M. incognita; Mj = M. javanica; Ma = M. arenaria

in Table 15. When the frequency of the three species was computed in total infected vegetable root samples collected from different localities of Aligarh district, it emerged that frequency of M. incognita was greater than other two species in all the localities except Atrauli where M. javanica was more frequent. In Aligarh city area also, frequency of M. javanica was slightly greater than M. incognita. However, in Hathras their frequencies were equal. In Sikandrarau, frequency of M. arenaria was much greater than M. javanica but lower than M. incognita (Fig.3, Table 15).

When the frequency of occurrence of the same species in different localities was compared, it was found that frequency of all the three species in total infected root samples was highest in Aligarh city area. Frequency of M. incognita in Aligarh city area was 63.01%. In other localities, its frequency ranged between 4.10% and 12.32%. Frequency of M. javanica in Aligarh city area was 69.65%. In rest of the localities, its frequency ranged between 0.99% and 19.90%. Frequency of M. arenaria was greater in Aligarh city area than in Sikandrarau and Atrauli (Fig.3, Table 15).

Identity and frequency of the races :

All the four races of M. incognita viz., Race 1, Race 2, Race 3 and Race 4 were found in the district (Fig.3, Table 16). Frequency of Race 1 of M. incognita was greater than Race 2 in all the localities where both were encountered except

Table 15. Frequency of occurrence of the species (%) of root-knot nematodes in different localities of Aligarh district based on total infected root samples of vegetables.

Locality	Total infected root samples	No.of root samples infected (single + mixed population)			Frequency of species in total infected samples		
		Mi	Mj	Ma	Mi	Mj	Ma
Aligarh city area	191	138	140	20	72.25* (63.01)**	73.29 (69.65)	10.47 (48.78)
Atrauli	40	21	40	5	52.50 (9.58)	100.00 (19.00)	12.50 (12.19)
Kasimpur	27	27	10	-	100.00 (12.32)	37.03 (4.97)	-
Hathras	11	9	9	-	81.81 (4.10)	81.81 (4.47)	-
Sikandrarau	24	24	2	16	100.00 (10.95)	8.33 (0.99)	66.66 (39.02)

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = M. incognita; Mj = M. javanica; Ma = M. arenaria

Table 16. Frequency of occurrence of races of *Meloidogyne incognita* (Mi) and *Meloidogyne arenaria* (Ma) in different localities of Aligarh district.

Locality	Species/Races	Frequency (%) of races of Mi				Frequency(%) of races of Ma	
		R_1	R_2	R_3	R_4	R_1	R_2
Aligarh city area	MaR_2, MiR_1, MiR_2, MiR_3, MiR_4	41.30* (69.51)**	32.60 (68.18)	3.62 (14.28)	22.46 (86.11)	-	100.00 (48.78)
Atrauli	MaR_2, MiR_1, MiR_2, MiR_3	57.14 (14.63)	28.57 (9.09)	14.28 (8.57)	-	-	100.00 (12.19)
Kasimpur	MiR_3	-	-	100.00 (77.14)	-	-	-
Hathras	MiR_1, MiR_2	55.55 (6.09)	44.44 (6.06)	-	-	-	-
Sikandrarau	MaR_2, MiR_1, MiR_2, MiR_4	33.33 (9.75)	45.83 (16.66)	-	20.83 (13.88)	-	100.00 (39.02)

* Values in rows represent frequency (%) of the races in the same locality.

** Values in parentheses in the columns of the races represent frequency (%) of the race in different localities.

Mi = *M. incognita*; Ma = *M. arenaria*

R_1 = Race 1, R_2 = Race 2, R_3 = Race 3 and R_4 = Race 4

Sikandrarau where frequency of Race 2 was greater than Race 1. In Aligarh city area, where all the 4 races were encountered, Race 1 was most frequent followed by Race 2 and Race 4. Race 3 was least frequent. Frequency of Race 4 was lower than Race 1 and Race 2 but greater than Race 3 in Aligarh city area. In Sikandrarau, its frequency was also lower than Race 1 and Race 2. In Kasimpur, only Race 3 of M. incognita was found (Table 16).

When frequency of a particular race among the localities was compared, it emerged that Race 1 was more frequent in Aligarh city area than Atrauli, Sikandrarau and Hathras. Frequency of Race 2 was also greatest in Aligarh city area among the localities. Its frequency in Sikandrarau, Atrauli and Hathras was comparatively low. Among the three localities where Race 3 was encountered, its frequency was greater in Kasimpur than Aligarh city area and Atrauli. Race 4 encountered in two localities, was more frequent in Aligarh city area than in Sikandrarau (Table 16).

In M. arenaria populations, only Race 2 was identified. Frequency of Race 2 of M. arenaria, among the 3 localities where it was encountered, was greater in Aligarh city area than Sikandrarau and Atrauli (Fig.3, Table 16).

2. BULANDSHAHR

Incidence and intensity of the disease :

Root samples of vegetables were collected from vegetable fields in five localities of Bulandshahr distrcit viz.,

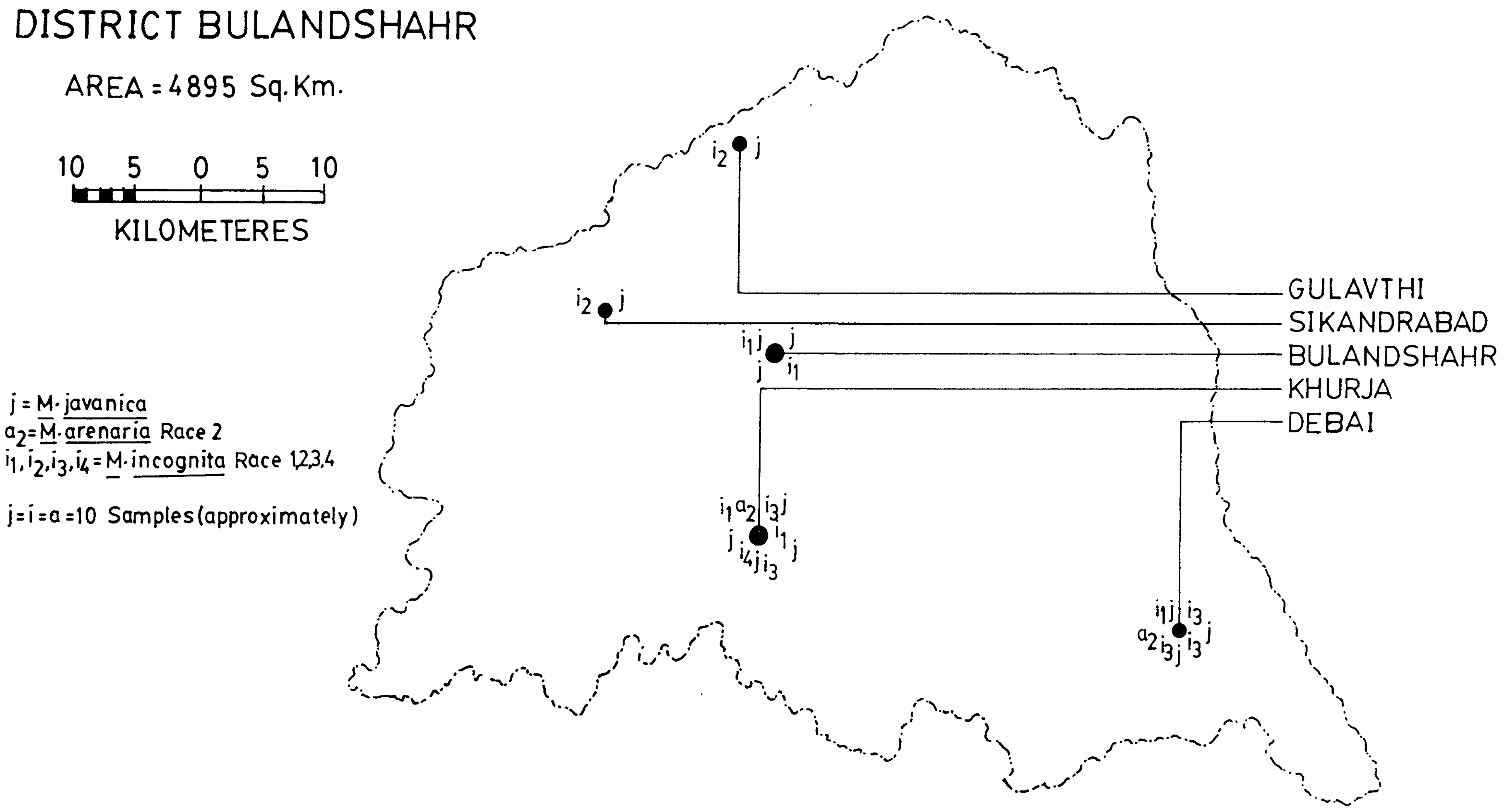


Fig.4: Distribution of root-knot nematodes and their races in district Bulandshahr.

Bulandshahr city area, Sikandrabad, Gulavthi, Debai and Khurja (Fig.4). The per cent frequency of the disease in vegetable fields of the different localities in the district ranged between 30 to 64.70. The incidence of the disease was highest in Khurja followed by Debai (Table 17).

When frequency of occurrence of the disease based on root samples was calculated, the frequency was found highest in Debai closely followed by Khurja. In Bulandshahr city area, Sikandrabad and Gulavthi it was below 25% (Table 17).

Gall index (GI) in infected root samples ranged from 2 to 5 and eggmass index (EMI) from 0 to 5 in the localities of the district. In some root samples from Debai there was no eggmass production but in other samples, EMI was 5. In rest of the localities, intensity based on EMI was mild to very severe through moderate and severe except in Sikandrabad where it was either severe or very severe. Intensity was from mild to very severe based on gall index. However, it varied from locality to locality. For example in Sikandrabad, the intensity was severe or very severe whereas in Khurja and Gulavthi it was moderate to very severe (Table 17).

Among the vegetables, incidence of the disease was highest in tomato fields (81.81%) closely followed by okra fields (80%). The incidence of the disease in eggplant, cucumber and pepper fields was also above 50%. But in cabbage fields the incidence was poor. Cauliflower fields were found free from infection.

Table 17. Incidence and intensity of root-knot nematodes on vegetable crops in different localities of Bulandshahr district.

Locality	Incidence						Intensity
	No.of cultivation units			No.of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Bulandshahr city area	20	11	55.00	200	39	19.50	2-5/2-5
Sikandrabad	10	3	30.00	100	14	14.00	4-5/4-5
Gulavthi	9	4	44.44	90	21	23.33	3-5/2-5
Debai	9	5	55.55	100	36	36.00	2-5/0-5
Khurja	17	11	64.70	170	60	35.29	3-5/3-5

GI = Gall index ; EMI = Eggmass index

The incidence of root-knot infection on roots was highest on tomato and lowest on cabbage. On eggplant and okra, frequency was equal (Table 18).

Highest intensity based on GI and EMI was observed on eggplant roots where GI was invariably 5 and EMI ranged from 4 to 5. It was followed by okra with GI/EMI as 4-5/4-5. On other vegetables, GI/EMI range was 2-5/0-5 (Table 18).

Identity and frequency of root-knot nematode species :

a. Identity of the species :-

M. incognita, *M. javanica* and *M. arenaria* were idenfieid infecting vegetables in Bulandshahr district (Fig.4, Table 19). Their single or mixed populations were found. Single populations of *M. incognita* or *M. javanica* and mixed populations of *M. incognita* and *M. javanica* or *M. incognita* and *M. arenaria* or *M. javanica* and *M. arenaria* were recorded (Table 19).

b. Frequency of the species in single and mixed populations :-

When the frequency of the single population of the species in different localities was compared, it was noticed that frequency of *M. incognita* was higher than *M. javanica* in Gulavthi and Khurja, whereas, frequency of *M. javanica* was much greater than *M. incognita* in Bulandshahr city area. In single population, *M. incognita* was absent only in Sikandrabad and *M. javanica* in Debai. When the frequencies of a species in

Table 18. Incidence and intensity of root-knot nematodes on different vegetable crops in Bulandshahr district.

Crop	Incidence						Intensity
	No.of cultivation units			No. of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Eggplant	13	9	69.23	130	52	40.00	5/4-5
Tomato	11	9	81.81	110	48	43.63	3-5/3-5
Pepper	12	7	58.33	130	41	31.53	2-5/0-5
Okra	5	4	80.00	50	20	40.00	4-5/4-5
Cucumber	6	4	66.66	60	8	13.33	2-5/2-5
Cauliflower	8	-	-	80	-	-	-
Cabbage	10	1	10.00	100	1	1.00	2/2

GI = Gall index; EMI = Eggmass index

different locality was analysed, it was found that frequency of *M. incognita* was highest in Khurja and of *M. javanica* in Bulandshahr city area. *M. arenaria* was not observed in single population in any locality (Table 19).

Mixed populations of *M. incognita* and *M. javanica* were found in all the localities except Gulavthi. *M. incognita* and *M. arenaria* in mixed population were present only in Debai with a very low frequency. *M. javanica* and *M. arenaria* in mixed population were found in Khurja also with a low frequency. When frequency of mixed populations of *M. incognita* and *M. javanica* was compared for different localities it was found greater in Debai than in Khurja, Bulandshahr city area and Sikandrabad. Frequency of mixed populations of *M. incognita* and *M. arenaria* in Debai and of *M. javanica* and *M. arenaria* in Khurja was 100% (Table 19).

c. Frequency of the species in total infected samples :-

When the frequency of species in total infected root samples irrespective of single or mixed population was computed, it was observed that frequency of *M. javanica* was greater than *M. incognita* in all the localities except Gulavthi and Debai. *M. arenaria* was present only in two localities (Debai and Khurja) with low frequencies (Fig.4, Table 20).

When frequency of a species among the localities on the basis of total samples was considered, frequency of *M. incognita* and *M. javanica* was higher in Khurja than in other localities.

Table 19. Frequency of occurrence of species (%) of root-knot nematodes in single and mixed populations on vegetable crops in different localities of Bulandshahr district.

Locality	Frequency of species						
	Single population			Mixed population			
	Mi	Mj	Ma	Mi+Mj	Mi+Ma	Mj+Ma	Mi+Mj+Ma
Bulandshahr city area	17.94* (14.89)**	58.97 (43.39)	-	23.07 (14.51)	-	-	-
Sikandrabad	-	64.28 (16.98)	-	35.71 (8.06)	-	-	-
Gulavthi	61.90 (27.65)	38.09 (15.09)	-	-	-	-	-
Debai	27.77 (21.27)	-	-	69.44 (40.32)	2.77 (100.00)	-	-
Khurja	28.33 (36.17)	21.66 (24.52)	-	38.33 (37.09)	-	11.66 (100.00)	-

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria*

Between the two localities where M.arenaria was encountered, its frequency was greater in Khurja than Debai (Fig.4, Table 20).

Identity and frequency of the races :

All the four races of M. incognita and Race 2 of M. arenaria were found to be present in the district (Fig.4, Table 21). Number of races present in a locality and their frequency showed variations. In Bulandshahr city area, only Race 1 and in Sikandrabad and Gulavthi only Race 2 of M.incognita were recorded. In Debai, where Race 1 and Race 3 of M. incognita were found, frequency of Race 3 was greater than Race 1. In Khurja, occurrence of Race 1, Race 3 and Race 4 of M. incognita was recorded. Frequency of Race 1 and of Race 3 was equal but greater than of Race 4 (Table 21).

Among the 3 localities, where Race 1 of M. incognita was encountered, its frequency was highest in Bulandshahr city area and Khurja and lowest in Debai. Among the two localities, where Race 2 of the M. incognita was encountered, its frequency was much greater in Gulavthi than in Sikandrabad. Race 3 encountered in two localities, showed greater frequency in Debai than in Khurja. Race 4 of M. incognita was recorded only from Khurja (Table 21).

In M. arenaria only Race 2 was identified to be present in its populations. Its frequency was much greater in Khurja than in Debai (Fig.4, Table 21).

Table 20. Frequency of occurrence of species (%) of root-knot nematodes in different localities of Bulandshahr district based on total infected root samples of vegetables.

Locality	Total infected root samples	No.of root samples infected (single + mixed populations)			Frequency of species in total infected samples		
		Mi	Mj	Ma	Mi	Mj	Ma
Bulandshahr city area	39	16	32	-	41.02* (14.54)**	82.05 (26.22)	-
Sikandrabad	14	5	14	-	35.71 (4.54)	100.00 (11.47)	-
Gulavthi	21	13	8	-	61.90 (11.81)	38.09 (6.55)	-
Debai	36	36	25	1	100.00 (32.72)	69.44 (20.49)	2.77 (12.50)
Khurja	60	40	43	7	66.66 (36.36)	71.66 (35.24)	11.66 (87.50)

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria*

Table 21. Frequency of occurrence of races of *Meloidogyne incognita* (Mi) and *Meloidogyne arenaria* (Ma) in different localities of Bulandshahr district.

Locality	Species/Races	Frequency(%) of races of Mi				Frequency(%) of races of Ma	
		R_1	R_2	R_3	R_4	R_1	R_2
Bulandshahr city area	MiR_1	100.00* (38.09)**	-	-	-	-	-
Sikandrabad	MiR_2	-	100.00 (27.77)	-	-	-	-
Gulavthi	MiR_2	-	100.00 (72.22)	-	-	-	-
Debai	MaR_2, MiR_1, MiR_3	27.77 (23.80)	-	72.22 (61.90)	-	-	100.00 (12.50)
Khurja	MaR_2, MiR_1, MiR_3, MiR_4	40.00 (38.09)	-	40.00 (38.09)	20.00 (100.00)	-	100.00 (87.50)

* Values in rows represent frequency (%) of the races in the same locality.

** Values in parentheses in the columns of the races represent frequency (%) of the races in different localities.

Mi = *M. incognita*; Ma = *M. arenaria*

R_1 = Race 1, R_2 = Race 2, R_3 = Race 3 and R_4 = Race 4

3. GHAZIABAD

Incidence and intensity of the disease :

In Ghaziabad district, five localities namely Ghaziabad city area, Pilkhua, Hapur, Garhmukteswar and Shahpur (Fig.5) were surveyed. The per cent field infestation of vegetables in different localities of the district ranged from 35.71 to 62.50. Incidence of the disease based on field infestation was highest in Shahpur (62.50%) followed by Ghaziabad city area and Garhmukteswar (50% each). Incidence of the disease in other localities was comparatively low. When root samples, collected from each locality were examined for root-knot infection, and frequency was calculated on root infection basis, highest incidence of the disease was found on roots collected from Shahpur (48.40%) followed by Pilkhua (34.54%). The lowest frequency was found in Hapur (Table 22).

Gall index (GI) and eggmass index (EMI) ranged from 2 to 5 and from 0 to 5 respectively in the district, showing very mild to very severe disease intensity. Localitywise variations were, however, noticed. In Hapur and Garhmukteswar, EMI range was 0-5 and 1-5 respectively, indicating no or poor eggmass production in some root samples. The intensity was severe to very severe (GI/EMI: 4-5/4-5) in Ghaziabad city area and Shahpur and very severe (GI/EMI: 5/5) in Pilkhua (Table 22).

Incidence of the disease in different vegetables fields regardless of localities showed that all the field of eggplant

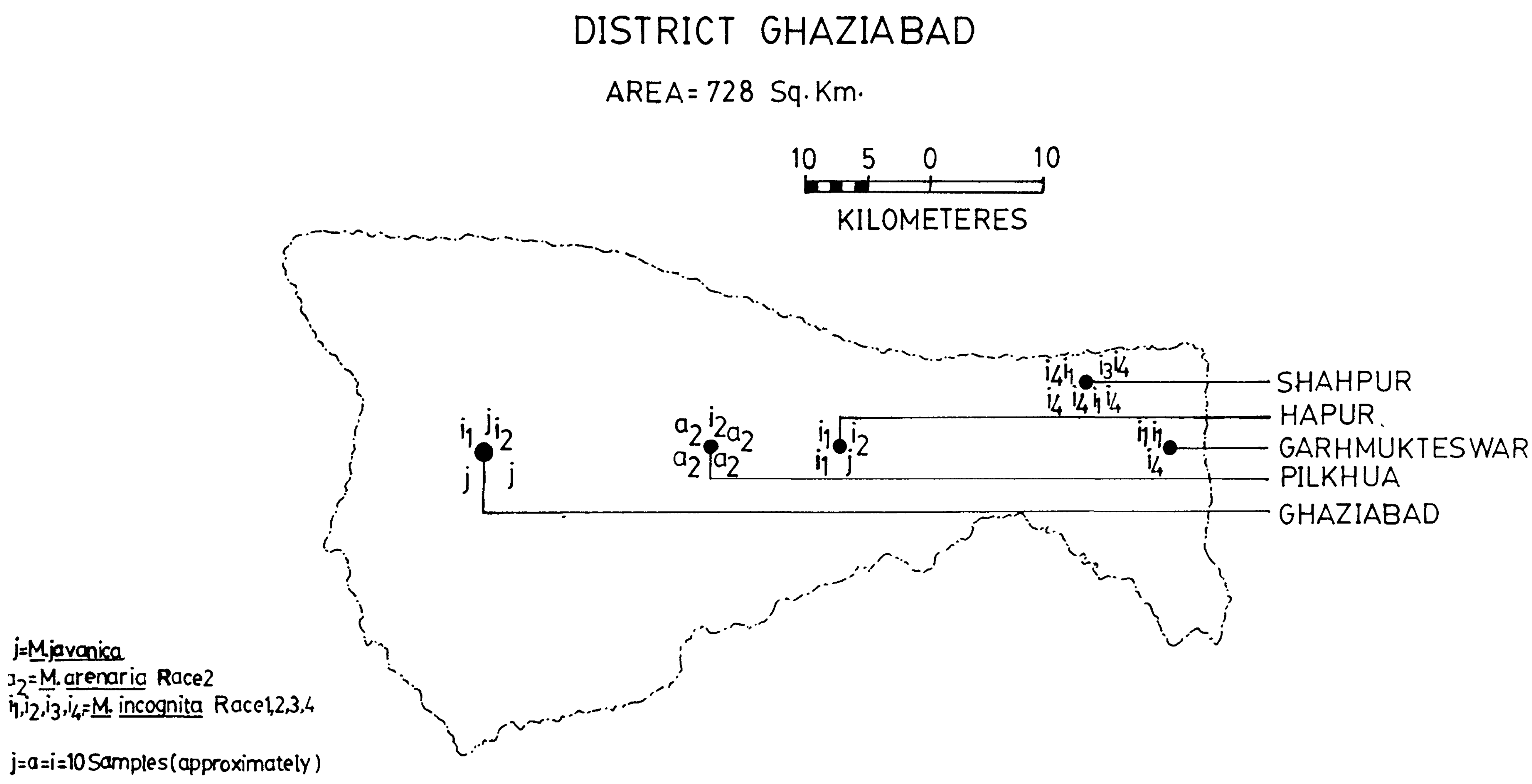


Fig. 5: Distribution of root-knot nematodes and their races in district Ghaziabad.

Table 22. Incidence and intensity of root-knot nematodes on vegetable crops in different localities of Ghaziabad district.

Locality	Incidence						Intensity
	No.of cultivation units			No.of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Ghaziabad city area	12	6	50.00	120	33	27.50	4-5/4-5
Pilkhua	11	5	45.45	110	38	34.54	5/5
Hapur	14	5	35.71	140	31	22.14	2-5/0-5
Garhmukteswar	8	4	50.00	80	26	32.50	2-5/1-5
Shahpur	16	10	62.50	157	76	48.40	4-5/4-5

GI = Gall index; EMI = Eggmass index

and okra were infested, frequency being 100%. Frequency of the disease was 57.14% and 46.66% in tomato and pepper fields respectively. Low incidence of the disease was observed in cauliflower (10%) and cabbage (8.33%) fields. No cultivation of cucumber was found during the survey (Table 23).

When the incidence of the disease based on infected root samples for each vegetable irrespective of the locality was determined, the incidence was highest on eggplant (72.85%) followed by okra (63.33%). Incidence of the disease on pepper and tomato roots was 34% and 32.85% respectively. Very low incidence (below 5%) was found on cabbage and cauliflower (Table 23).

Intensity of the disease on different vegetables also showed variations. GI/EMI ranges were 2-5/0-5 on eggplant, 3-5/2-5 on tomato, 2-5/2-5 on pepper, 3-5/1-5 on okra, 4/4 on cauliflower and 5/5 on cabbage (Table 23).

Identity and frequency of root-knot nematode species :

a. Identity of the species :-

M. incognita, *M. javanica* and *M. arenaria* were found to be present in Ghaziabad district (Fig.5, Table 24). All the three species were found singly or concomitantly on the roots of vegetables. Mixed populations of *M. incognita* and *M. javanica* and of *M. incognita* and *M. arenaria* were found (Table 24).

Table 23. Incidence and intensity of root-knot nematodes on different vegetable crops in Ghaziabad district.

Crop	Incidence						Intensity
	No.of cultivation units			No. of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Eggplant	14	14	100.00	140	102	72.85	2-5/0-5
Tomato	7	4	57.14	70	23	32.85	3-5/2-5
Pepper	15	7	46.66	150	51	34.00	2-5/2-5
Okra	3	3	100.00	30	19	63.33	3-5/1-5
Cucumber	-	-	-	-	-	-	-
Cauliflower	10	1	10.00	97	4	4.12	4/4
Cabbage	12	1	8.33	120	5	4.16	5/5

GI = Gall index; EMI = Eggmass index

b. <u>Frequency of the species in single and mixed populations</u> :-

Single populations of *M. incognita* were observed in all the localities except Pilkhua. In Pilkhua, only *M. arenaria* was found in single populations. *M. javanica* in single populations was recorded from 2 localities viz., Ghaziabad city area and Hapur. In single populations, frequency of *M. javanica* was greater than *M. incognita* in Ghaziabad city area. But frequency of *M. incognita* was greater than *M. javanica* in Hapur. Frequency of *M. incognita* was higher in Shahpur than in other localities. Of two localities in which *M. javanica* was encountered, its frequency was much greater in Ghaziabad city area than in Hapur (Table 24).

Mixed population of *M. incognita* and *M. javanica* recorded from Ghaziabad city area and Hapur was more frequent in the former than in latter locality. *M. incognita* mixed with *M. arenaria* was found only in Pilkhua (Table 24).

c. <u>Frequency of the species in total infected samples</u> :-

In total infected root samples, frequency of *M. javanica* was greater than *M. incognita* in Ghaziabad city area. But in Hapur frequency of *M. incognita* was greater than *M. javanica*. In all the infected samples collected from Pilkhua *M. arenaria* was present either singly or concomitantly with *M. incognita*. Therefore, its frequency was 100%. Frequency of *M. incognita* in Pilkhua was 18.42%. In Garhmukteswar and Shahpur only *M. incognita*

Table 24. Frequency of occurrence of species (%) of root-knot nematodes in single and mixed populations on vegetable crops in different localities of Ghaziabad district.

Locality	Frequency of species						
	Single population			Mixed population			
	Mi	Mj	Ma	Mi+Mj	Mi+Ma	Mj+Ma	Mi+Mj+Ma
Ghaziabad city area	21.21* (5.55)**	42.42 (66.66)	-	36.36 (63.15)	-	-	-
Pilkhua	-	-	81.57 (100.00)	-	18.42 (100.00)	-	-
Hapur	54.83 (13.49)	22.58 (33.33)	-	22.58 (36.84)	-	-	-
Garhmukteswar	100.00 (20.63)	-	-	-	-	-	-
Shahpur	100.00 (60.31)	-	-	-	-	-	-

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different locality.

Mi= *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria* was encountered in all the infected samples, frequency being 100% in both the localities (Fig.5, Table 25).

When comparative assessment of frequencies of M. incognita in different localities was done, it appeared that its frequency was greater in Shahpur than in other localities. M. javanica recorded in two localities, was more frequent in Ghaziabad city area than in Hapur. However, frequency of M. arenaria was 100% as it was recorded only in Pilkhua (Table 25).

Identity and frequency of the races :

All the four races of M. incognita and Race 2 of M.arenaria were recorded from the district (Fig.5, Table 26). In Ghaziabad city area and Hapur, Race 1 and Race 2; in Garhmukteswar, Race 1 and Race 4; in Shahpur, Race 1, Race 3 and Race 4; and in Pilkhua, Race 2 of M. incognita were encountered. In Pilkhua, in addition to Race 2 of M. incognita, Race 2 of M. arenaria was also found. In Ghaziabad city area and Hapur, frequency of Race 1 was greater than Race 2 and in Garhmukteswar greater than Race 4. However, in Shahpur, frequency of Race 4 was greater than Race 1 and Race 3 (Table 26).

Among the localities, frequency of Race 1 was greater in Garhmukteswar than other localities. In Hapur, frequency of Race 2 was higher than any other locality where it was encountered. Race 3 occurred only in Shahpur. Between two localities where Race 4 was encountered, its frequency was much greater in Shahpur

Table 25. Frequency of occurrence of species (%) of root-knot nematodes in different localities of Ghaziabad district based on total infected root samples of vegetables.

Locality	Total infected root samples	No.of root samples infected (single + mixed populations)			Frequency of species in total infected samples		
		Mi	Mj	Ma	Mi	Mj	Ma
Ghaziabad city area	33	19	26	-	57.57* (12.50)**	78.78 (65.00)	-
Pilkhua	38	7	-	38	18.42 (4.60)	-	10C.00 (1C0.00)
Hapur	31	24	14	-	77.41 (15.78)	45.16 (35.00)	-
Garhmukteswar	26	26	-	-	100.00 (17.10)	-	-
Shahpur	76	76	-	-	100.00 (50.00)	-	-

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = M. incognita; Mj = M. javanica; Ma = M. arenaria

Table 26. Frequency of occurrence of races of *Meloidogyne incognita* (Mi) and *Meloidogyne arenaria* (Ma) in different localities of Ghaziabad district.

Locality	Species/Races	Frequency(%) of races of Mi				Frequency(%) of races of Ma	
		R_1	R_2	R_3	R_4	R_1	R_2
Ghaziabad city area	MiR_1, MiR_2	73.68* (20.28)**	26.31 (23.80)	-	-	-	-
Pilkhua	MaR_2, MiR_2	-	100.00 (33.33)	-	-	-	100.00 (100.00)
Hapur	MiR_1, MiR_2	62.50 (21.73)	37.50 (42.85)	-	-	-	-
Garhmukteswar	MiR_1, MiR_4	76.92 (28.98)	-	-	23.07 (11.53)	-	-
Shahpur	MiR_1, MiR_3, MiR_4	26.31 (18.98)	-	13.15 (100.00)	60.52 (88.46)	-	-

* Values in rows represent frequency (%) of the races in the same locality.

** Values in parentheses in the columns of the races represent frequency (%) of the race in different localities.

Mi = *M. incognita*; Ma = *M. arenaria*

R_1 = Race 1, R_2 = Race 2, R_3 = Race 3 and R_4 = Race 4

than Garhmukteswar. Frequency of M. arenaria Race 2 was 100% in Pilkhua (Table 26).

4. MEERUT

Incidence and intensity of the disease :

Survey was conducted in Meerut city area, Kharkhauda, Baghpat, Shahjahanpur and Kithaur localities in Meerut district (Fig.6). In the localities of Meerut district, 50-80.95% fields of vegetables were infested with root-knot nematodes. The incidence of the disease in vegetable fields was highest in Baghpat (80.95%) followed by Kithaur (63.63%) and Meerut city area (60%). Fifty per cent incidence was recorded both in Kharkhauda and Shahjahanpur (Table 27).

In root samples, frequency of root-knot infection was highest in Baghpat (50.95%) followed by Shahjahanpur (40%). In Kithaur, and in Meerut city area it was slightly lower. Lowest frequency (12%) was observed in Kharkhauda (Table 27).

Highest intensity of the disease in terms of gall index (GI) and eggmass index (EMI) was observed in Shahjahanpur and Kithaur. The intensity range was from severe to very severe in both localities. In Meerut city area and Baghpat, eggmass indices were between 0 to 5 which showed that some roots were free from eggmasses but on some other roots eggmass production was high. However, in Kharkhauda, eggmass indices on roots were mild (2) (Table 27).

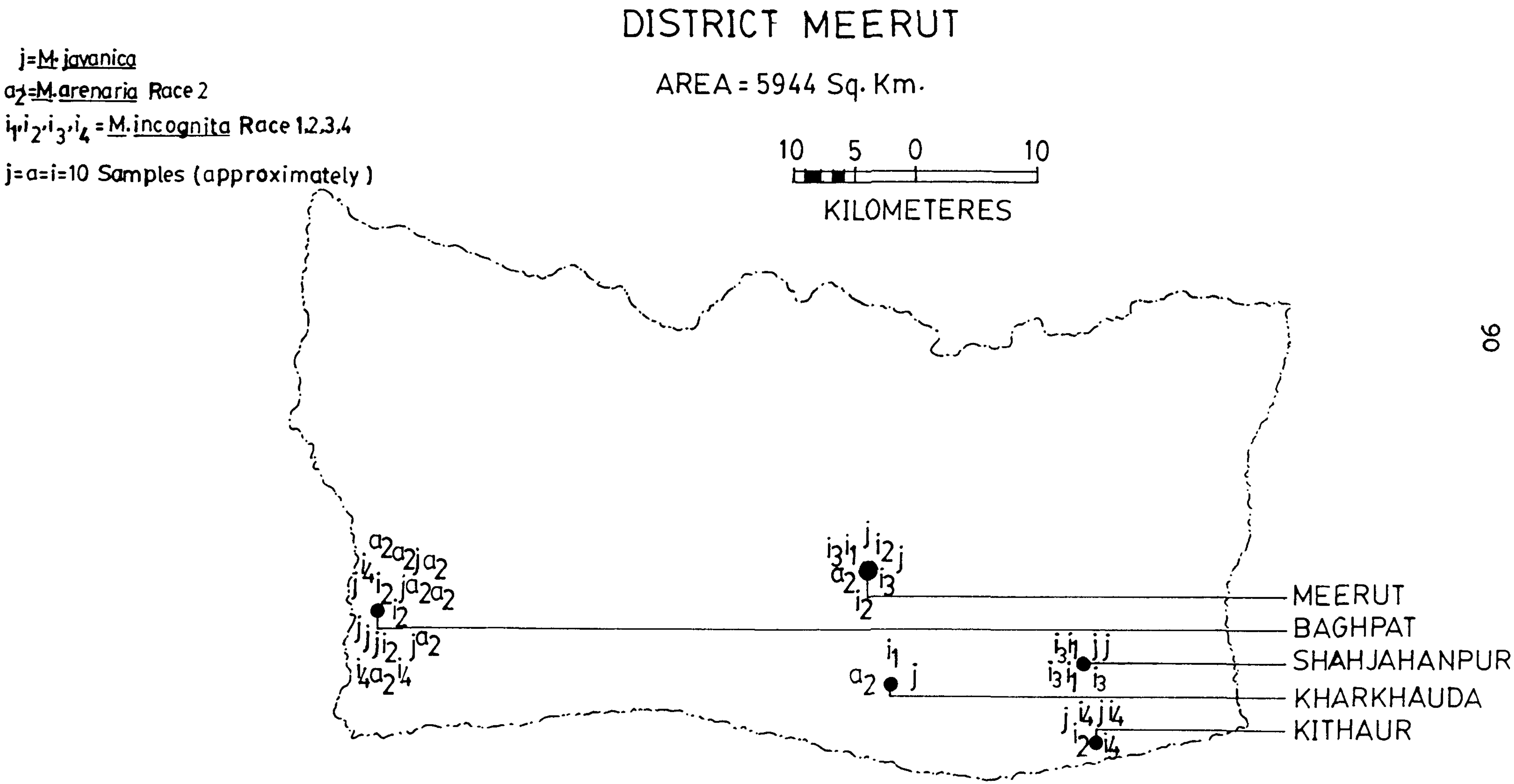


Fig.6: Distribution of root-knot nematodes and their races in district Meerut.

Table 27. Incidence and intensity of root-knot nematodes on vegetable crops in different localities of Meerut district.

Locality	Incidence						Intensity
	No.of cultivation units			No. of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Meerut city area	15	9	60.00	150	51	34.00	2-5/0-5
Kharkhauda	6	3	50.00	75	9	12.00	3-4/2
Baghpat	21	17	80.95	210	109	50.95	2-5/0-5
Shahjahanpur	12	6	50.00	120	48	40.00	4-5/4-5
Kithaur	11	7	63.63	110	40	36.36	4-5/4-5

GI = Gall index; EMI = Eggmass index

Incidence of the disease was highest (100%) in eggplant and cucumber fields. Frequency of the disease in fields of tomato, pepper and okra ranged between 42.10 and 69.23%. Cauliflower and cabbage crops encountered during the survey were free from the disease (Table 28).

On root-sample basis, highest frequency was observed on cucumber roots (77.77%) followed by eggplant (52.85%), okra (39.23%), tomato (24%) and pepper (22.10%) (Table 28).

Intensity of the disease was generally severe to very severe on pepper as GI/EMI were 4-5/4-5. Almost same intensity was found on cucumber. On tomato, eggplant, and okra roots, the intensity ranged from nil to very severe (GI/EMI:2-5/0-5). On some eggplant and okra roots, no eggmass development was found at the time of survey (Table 28).

<u>Identity and frequency of root-knot nematode species</u> :

a. <u>Identity of the species</u> :-

From the district, <u>M</u>. <u>incognita</u>, <u>M</u>. <u>javanica</u> and <u>M</u>.<u>arenaria</u> were identified to be present on vegetables. They were present either in single or in mixed populations in the localities of the district (Fig.6, Table 29).

b. <u>Frequency of the species in single and mixed populations</u> :-

Frequency of single population of <u>M</u>. <u>incognita</u> was greater than <u>M</u>. <u>javanica</u> in Meerut city area. But in Baghpat, frequency

Table 28. Incidence and intensity of root-knot nematodes on different vegetable crops in Meerut district.

Crop	Incidence						Intensity
	No. of cultivation units			No. of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Eggplant	12	12	100.00	140	74	52.85	3-5/0-5
Tomato	8	4	50.00	75	18	24.00	2-5/2-4
Pepper	19	8	42.10	190	42	22.10	4-5/4-5
Okra	13	9	69.23	130	51	39.23	2-5/0-5
Cucumber	9	9	100.00	90	70	77.77	4-5/3-5
Cauliflower	1	-	-	10	-	-	-
Cabbage	3	-	-	30	-	-	-

GI = Gall index; EMI = Eggmass index

of single population of *M. javanica* was greater than *M. incognita* and *M. arenaria*. However, from other three localities (Kharkhauda, Shahjahanpur and Kithaur) only *M. incognita* was recorded in single populations with frequency above 50% in each locality. When frequency of a species was compared among the localities, it emerged that *M. incognita* was more frequent in Shahjahanpur than in rest of the localities. *M. javanica* encountered in two localities, was more frequent in Baghpat than in Meerut city area. *M. arenaria* was found in single population in Baghpat, so its frequency was 100% (Table 29).

Mixed populations of the two species or all the three were present on the same root systems. Variations in frequencies of different combination of species were found. In Meerut city area, the frequency of *M. incognita* and *M. javanica* was greater than *M. incognita* and *M. arenaria* or *M. incognita*, *M. javanica* and *M. arenaria*. In Kharkhauda, frequency of mixed populations of *M. incognita* and *M. arenaria* was greater than *M. incognita*, *M. javanica* and *M. arenaria*. In Baghpat frequency of mixed populations of all the three species was greater than *M. incognita* and *M. arenaria* or *M. javanica* and *M. arenaria*. From Shahjahanpur and Kithaur only *M. incognita* and *M. javanica* was recorded in mixed population (Table 29).

In localities, frequency of mixed populations of *M. incognita* and *M. javanica* was higher in Kithaur than in Shahjahanpur and Meerut city area. Frequency of mixed populations of *M. incognita* and *M. arenaria* was greater in Baghpat

Table 29. Frequency of occurrence of species (%) of root-knot nematodes in single and mixed populations on vegetable crops in different localities of Meerut district.

Locality	Frequency of species						
	Single population			Mixed population			
	Mi	Mj	Ma	Mi+Mj	Mi+Ma	Mj+Ma	Mi+Mj+Ma
Meerut city area	47.05* (24.48)**	3.92 (6.45)	-	23.52 (27.27)	5.88 (14.28)	-	19.60 (25.64)
Kharkhauda	55.55 (5.10)	-	-	-	33.33 (14.28)	-	11.11 (2.56)
Baghpat	12.14 (13.26)	27.10 (93.54)	4.67 (100.00)	-	14.01 (71.42)	15.88 (100.00)	26.16 (71.79)
Shahjahanpur	68.75 (33.67)	-	-	31.25 (34.09)	-	-	-
Kithaur	57.50 (23.46)	-	-	42.50 (38.63)	-	-	-

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria*

than Meerut city area and Kharkhauda. Frequency of all the three species in mixed populations was also much greater in Baghpat than Meerut city area and Kharkhauda. Mixed population of M. javanica and M. arenaria was encountered only from Baghpat (Table 29).

c. Frequency of the species in total infected samples :-

In total infected samples, frequency of M. incognita was greater than M. javanica in all the localities except Baghpat where its frequency was lower than M. javanica and M. arenaria. In Kharkhauda, frequency of M. arenaria was greater than M. javanica but lower than M. incognita. Frequency of M.arenaria was lowest than other two species in Meerut city area (Fig.6, Table 30).

In total infected samples, frequency of all the three species individually was greater in Baghpat than in other localities (Table 30).

Identity and frequency of the races :

All the four races of M. incognita and Race 2 of M. arenaria were recorded in the district (Fig.6, Table 31). But their distribution and frequency varied. In Meerut city area, Race 1, Race 2 and Race 3; in Kharkhauda Race 1; in Baghpat and Kithaur Race 2 and Race 4; and Shahjahanpur Race 1 and Race 3 of M. incognita were recorded. In Meerut city area, frequency of

Table 30. Frequency of occurrence of species (%) of root-knot nematodes in different localities of Meerut district based on total infected root samples of vegetables.

Locality	Total infected root samples	No.of root samples infected (single + mixed populations)			Frequency of species in total infected samples		
		Mi	Mj	Ma	Mi	Mj	Ma
Meerut city area	51	49	24	13	96.07* (24.25)**	47.05 (18.32)	25.49 (15.85)
Kharkhauda	9	9	1	4	100.00 (4.45)	11.11 (0.76)	44.44 (4.87)
Baghpat	107	56	74	65	52.33 (27.72)	69.15 (56.48)	60.74 (79.26)
Shahjahanpur	48	48	15	-	100.00 (23.76)	31.25 (11.45)	-
Kithaur	40	40	17	-	100.00 (19.80)	42.50 (12.97)	-

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = <u>M</u>. <u>incognita</u>; Mj = <u>M</u>. <u>javanica</u>; Ma = <u>M</u>. <u>arenaria</u>

Table 31. Frequency of occurrence of races of <u>Meloidogyne incognita</u> (Mi) and <u>Meloidogyne arenaria</u> (Ma) in different localities of Meerut district.

Locality	Species/Races	Frequency (%) of races of Mi				Frequency(%) of races of Ma	
		R_1	R_2	R_3	R_4	R_1	R_2
Meerut city area	MaR_2, MiR_1, MiR_2, MiR_3	28.57* (30.43)**	30.61 (28.30)	40.81 (44.44)	-	-	100.00 (15.85)
Kharkhauda	MaR_2, MiR_1	100.00 (19.56)	-	-	-	-	100.00 (4.87)
Baghpat	MaR_2, MiR_2, MiR_4	-	57.14 (60.37)	-	42.85 (41.37)	-	100.00 (79.26)
Shahjahanpur	MiR_1, MiR_3	47.91 (50.00)	-	52.08 (55.55)	-	-	-
Kithaur	MiR_2, MiR_4	-	15.00 (11.32)	-	85.00 (58.62)	-	-

* Values in rows represent frequency (%) of the races in the same locality.

** Values in parentheses in the columns of the races represent frequency (%) of the race in different localities.

Mi = <u>M. incognita</u>; Ma = <u>M. arenaria</u>

R_1 = Race 1, R_2 = Race 2, R_3 = Race 3 and R_4 = Race 4

Race 3 was greater than Race 2 and Race 1. In Kharkhauda, only Race 1 of *M. incognita* was encountered. In Baghpat frequency of Race 2 was greater than Race 4. But, frequency of Race 4 was greater than Race 2 in Kithaur. In Shahjahanpur, frequency of Race 3 was greater than Race 1 (Table 31).

Frequency of Race 1 of *M. incognita* was highest in Shahjahanpur followed by Meerut city area and Kharkhauda. Frequency of Race 2 was much higher in Baghpat than in other localities. Frequency of Race 3 was greater in Shahjahanpur than Meerut city area. Race 4 was more frequent in Kithaur than Baghpat (Fig.6, Table 31).

In *M. arenaria* populations only Race 2 was present in the district. Therefore, its frequency was 100% in all three localities where it was found. Among the localities,its frequency was greater in Baghpat than Meerut city area and Kharkhauda (Fig.6, Table 31).

5. MUZAFFARNAGAR

Incidence and intensity of the disease :

Muzaffarnagar city area, Pautikhurd, Jalalabad, Khatauli and Thana Bhawan localities of Muzaffarnagar district were surveyed (Fig.7). The per cent infestation of vegetable fields in different localities of the district varied from 14.28 to 83.33%. Incidence of the disease was highest in vegetable fields

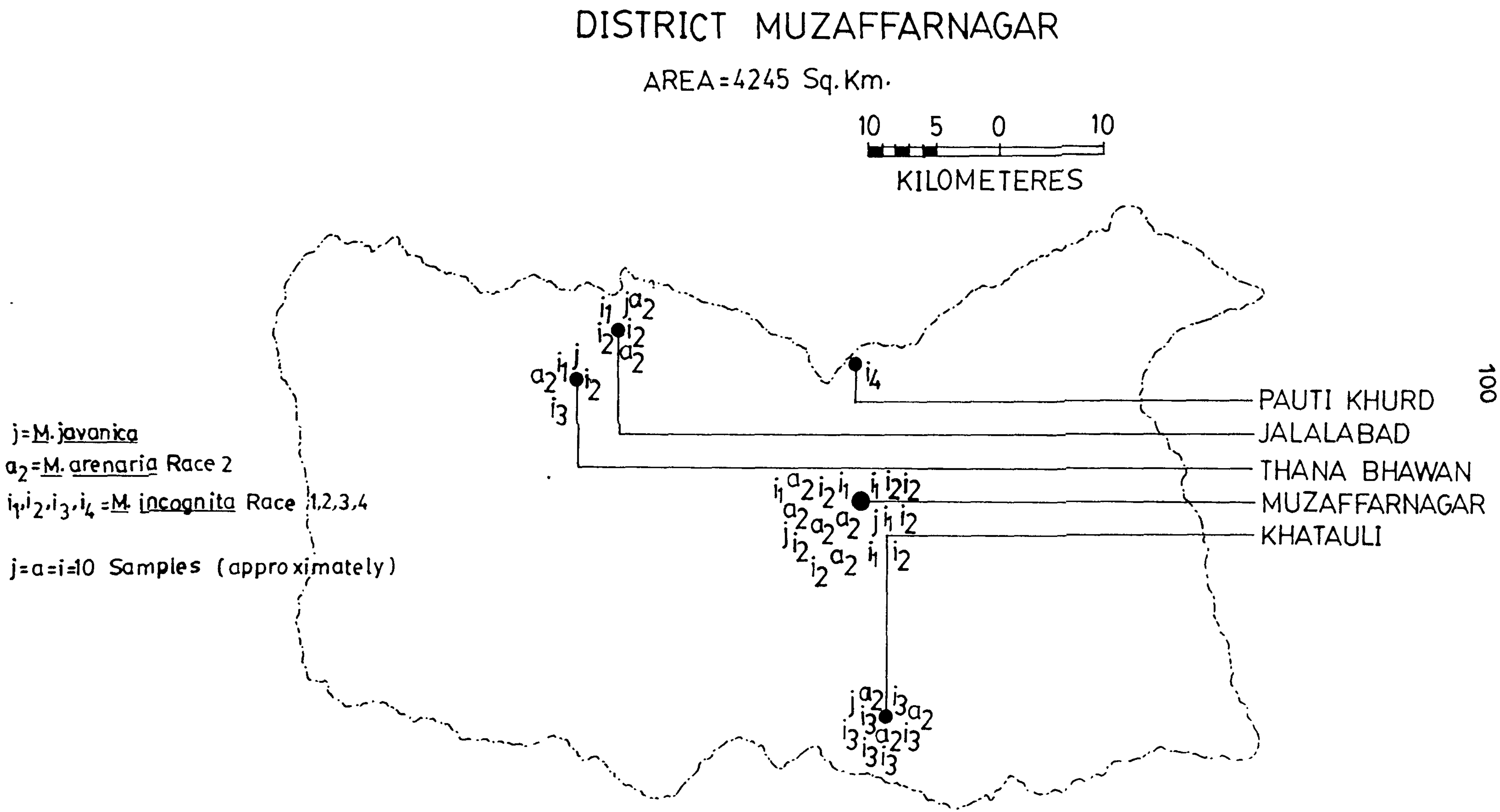


Fig.7: Distribution of root-knot nematodes and their races in district Muzaffarnagar.

of Khatauli irrespective of the crop grown followed by Thana Bhawan, Jalalabad and Muzaffarnagar city area. Lowest frequency was observed in Pautikhurd. On root sample basis, the incidence was also higher in Khatauli than in other localities (Table 32).

Intensity of the disease was mild, moderate, severe or very severe in the district, showing localitywise variations. Gall Index (GI) ranged between 3 and 5 and eggmass index (EMI) between 1 and 5 in the localities (Table 32).

The incidence of the disease in pepper fields was higher than in eggplant, okra, cucumber, tomato and cauliflower fields. Incidently only one field was found grown with cabbage during the survey which was infested. On root sample, basis, incidence was highest on cucumber followed by okra, cabbage, tomato, eggplant, pepper and cauliflower in decreasing order (Table 33).

Intensity of the disease was highest on cucumber and eggplant as GI/EMI were 5/5, 4-5/4-5 respectively. GI/EMI was 3-5/3-5 on tomato; 3-5/2-5 on okra; 3-5/1-5 on pepper; 4/3 on cauliflower; and 3/3 on cabbage roots (Table 33).

<u>Identity and frequency of root-knot nematode species</u> :

a. <u>Identity of the species</u> :-

M. incognita, *M. javanica* and *M. arenaria* were recorded in the district (Fig.7, Table 34).

Table 32. Incidence and intensity of root-knot nematodes on vegetable crops in different localities of Muzaffarnagar district.

Locality	Incidence						Intensity
	No.of cultivation units			No.of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Muzaffarnagar city area	16	11	68.75	186	135	72.58	3-5/3-5
Pautikhurd	7	1	14.28	44	7	15.90	5/5
Jalalabad	7	5	71.42	80	31	38.75	3-5/1-5
Khatauli	6	5	83.33	87	64	73.56	3-5/2-5
Thana Bhawan	8	6	75.00	80	26	32.50	3-5/2-5

GI = Gall index; EMI = Eggmass index

Table 33. Incidence and intensity of root-knot nematodes on different vegetable crops in Muzaffarnagar district.

Crop	Incidence						Intensity
	No.of cultivation units			No.of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Eggplant	10	6	60.00	97	46	47.42	4-5/4-5
Tomato	5	2	40.00	34	17	50.00	3-5/3-5
Pepper	14	12	85.71	162	76	46.91	3-5/1-5
Okra	7	4	57.14	84	56	66.66	3-5/2-5
Cucumber	4	2	50.00	80	60	75.00	5/5
Cauliflower	3	1	33.33	15	5	33.33	4/3
Cabbage	1	1	100.00	5	3	60.00	3/3

GI = Gall index; EMI = Eggmass index

b. Frequency of the species in single and mixed populations :-

In single population, M. incognita was present in all the localities but single population of M. javanica was found only in Muzaffarnagar city area. M. arenaria was not found in single population in the district. In Muzaffarnagar city area, the frequency of M. incognita was much greater than M. javanica. Among the localities, frequency of M. incognita was greater in Muzaffarnagar city area than in Khatauli, Thana Bhawan, Pautikhurd and Jalalabad. Since M. javanica was present only in Muzaffarnagar city area, its frequency was 100% (Table 34).

In mixed populations, M. incognita with M. javanica or M. incognita with M. arenaria or M. javanica with M. arenaria or M. incognita with M. javanica and M. arenaria were present on roots in the district. M. incognita and M. javanica combination was present in Jalalabad and Thana Bhawan, M. javanica and M. arenaria in Muzaffarnagar city area, Khatauli, and M. incognita and M. arenaria combination in Muzaffarnagar city area, Jalalabad, Khatauli and Thana Bhawan. Combination of the three species was found only in Khatauli. In Muzaffarnagar city area and Khatauli, the frequency of M. incognita and M.arenaria was greater than M. javanica and M. arenaria in mixed populations. In Jalalabad, frequency of mixed populations of M. incognita and M. arenaria was greater than M. incognita and M. javanica combination. However, in Thana Bhawan, frequencies of these two combinations were equal. In Khatauli, frequency of M. incognita and

Table 34. Frequency of occurrence of species (%) of root-knot nematodes in single and mixed populations on vegetable crops in different localities of Muzaffarnagar district.

Locality	Frequency of species						
	Single population			Mixed population			
	Mi	Mj	Ma	Mi+Mj	Mi+Ma	Mj+Ma	Mi+Mj+Ma
Muzaffarnagar city area	62.96* (60.28)**	3.70 (100.00)	-	-	25.92 (44.87)	7.40 (71.42)	-
Pautikhurd	100.00 (4.96)	-	-	-	-	-	-
Jalalabad	22.58 (4.96)	-	-	29.03 (52.94)	48.38 (19.23)	-	-
Khatauli	50.00 (22.69)	-	-	-	31.25 (25.64)	6.25 (28.57)	12.50 (100.00)
Thana Bhawan	38.46 (7.09)	-	-	30.76 (47.05)	30.76 (10.25)	-	-

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria*

M. arenaria was greater than M. javanica and M. arenaria combination or combination of all the three species. No mixed population of root-knot nematodes was found in Pautikhurd (Table 34).

Within different localities, frequency of mixed populations of M. incognita and M. javanica was greater in Jalalabad than in Thana Bhawan and of M. javanica and M. arenaria was greater in Muzaffarnagar city area than Khatauli. Frequency of M. incognita and M. arenaria combination was higher in Muzaffarnagar city area than in Khatauli, Jalalabad and Thana Bhawan. All the three species in mixed populations were found only in Khatauli. Accordingly, the frequency was 100% (Table 34).

c. Frequency of the species in total infected samples :-

In total infected samples regardless of single or mixed populations, species showed variations in their frequency in different localities. Frequency of M. incognita was highest in all the localities. It was followed by M. arenaria. Frequency of M. javanica in each locality was lower than M. incognita or M. arenaria except in Thana Bhawan where its frequency equalled with M. arenaria (Fig.7, Table 35).

Frequency of M. incognita in total infected samples between the localities was highest in Muzaffarnagar city area (49.18%). In rest of the localities, frequency range was between 2.86% and 24.59%. Frequency of M. javanica and M. arenaria was also higher in Muzaffarnagar city area than in other localities (Table 35).

Table 35. Frequency of occurrence of species (%) of root-knot nematodes in different localities of Muzaffarnagar district based on total infected root samples of vegetables.

Locality	Total infected root samples	No.of root samples infected (single + mixed populations)			Frequency of species in total samples with infection		
		Mi	Mj	Ma	Mi	Mj	Ma
Muzaffarnagar city area	135	120	15	45	88.88* (49.18)**	11.11 (34.09)	33.33 (45.00)
Pautikhurd	7	7	-	-	100.00 (2.86)	-	-
Jalalabad	31	31	9	15	100.00 (12.70)	29.58 (20.45)	48.38 (15.00)
Khatauli	64	60	12	32	93.75 (24.59)	18.75 (27.27)	50.00 (32.00)
Thana Bhawan	26	26	8	8	100.00 (10.65)	30.76 (18.18)	30.76 (8.00)

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria*

Identity and frequency of the races :

All the four races of *M. incognita* and Race 2 of *M. arenaria* were recorded from the district. Race 1 and Race 2 of *M. incognita* were found in three localities; Race 3 in two localities and Race 4 in one locality. Frequency of Race 2 was greater than Race 1 in all the three localities where it was found with Race 1. In Thana Bhawan, Race 2 and Race 3 were equally frequent. In Pautikhurd, only Race 4 and in Khatauli Race 3 were found. Consequently, their frequency was 100% in these localities (Fig.7, Table 36).

Among the localities of encounterance, frequency of Race 1 of *M. incognita* was greater in Muzaffarnagar city area than in Jalalabad and Thana Bhawan. Frequency of Race 2 was also higher in Muzaffarnagar city area than in other two localities. Out of two localities in which Race 3 was found, its frequency was much greater in Khatauli than in Thana Bhawan. Race 4 being present only in one locality (Pautikhurd) showed 100% frequency (Fig.7, Table 36).

In *M. arenaria* populations only Race 2 was found to be present irrespective of the locality. Therefore, its frequency was 100% in each locality. Between the localities, its frequency was higher in Muzaffarnagar city area than in other three localities (Fig.7, Table 36).

Table 36. Frequency of occurrence of races of *Meloidogyne incognita* (Mi) and *Meloidogyne arenaria* (Ma) in different localities of Muzaffarnagar district.

Locality	Species/Races	Frequency(%) of races of Mi				Frequency(%) of races of Ma	
		R_1	R_2	R_3	R_4	R_1	R_2
Muzaffarnagar city area	MaR_2, MiR_1, MiR_2	41.66* (79.36)**	58.33 (67.30)	-	-	-	100.00 (45.00)
Pautikhurd	MiR_4	-	-	-	100.00 (100.00)	-	-
Jalalabad	MaR_2, MiR_1, MiR_2	22.58 (11.11)	77.41 (23.07)	-	-	-	100.00 (15.00)
Khatauli	MaR_2, MiR_3	-	-	100.00 (85.71)	-	-	100.00 (32.00)
Thana Bhawan	MaR_2, MiR_1, MiR_2, MiR_3	23.07 (9.52)	38.46 (9.61)	38.46 (14.28)	-	-	100.00 (8.00)

* Values in rows represent frequency (%) of the races in the same locality.

** Values in parentheses in the columns of the races represent frequency (%) of the race in different localities.

Mi = *M. incognita*; Ma = *M. arenaria*

R_1 = Race 1, R_2 = Race 2, R_3 = Race 3 and R_4 = Race 4

6. SAHARANPUR

Incidence and intensity of the disease :

Five localities of Saharanpur district were surveyd (Fig.8) to assess the incidence and intensity of the disease on vegetable crops. The incidence of the disease in vegetable fields of the different localities showed variations, ranging from 28.57% to 88.88%. The highest incidence (88.88%) was found in Deoband followed by Saharanpur city area (66.66%). The frequency of the disease in the root sample was 46.92% in Saharanpur city area, 13.75% in Manglaur, 50.55% in Deoband, 25.72% in Roorkee and 23.27% in Chutmalpur (Table 37).

The intensity range of the disease was moderate to very severe (3-5) based on GI in all the localities except Manglaur where the disease was severe. EMI showed much variations. On some root samples, collected from Deoband no eggmass production was noticed. In general, EMI ranged between 2-5 (Table 37).

Among the vegetables, highest incidence of the disease (100%) as found in cucumber fields. Eggplant fields with 92.85% and tomato fields with 80% frequencies were next in the order. The incidence of the disease was 45% both in pepper and okra fields. Lowest incidence was observed in cauliflower fields (20%). Cabbage fields were free from infestation. On root samples, frequency of the disease was highest on tomato followed by cucumber. Lowest frequency was noticed on cauliflower (Table 38).

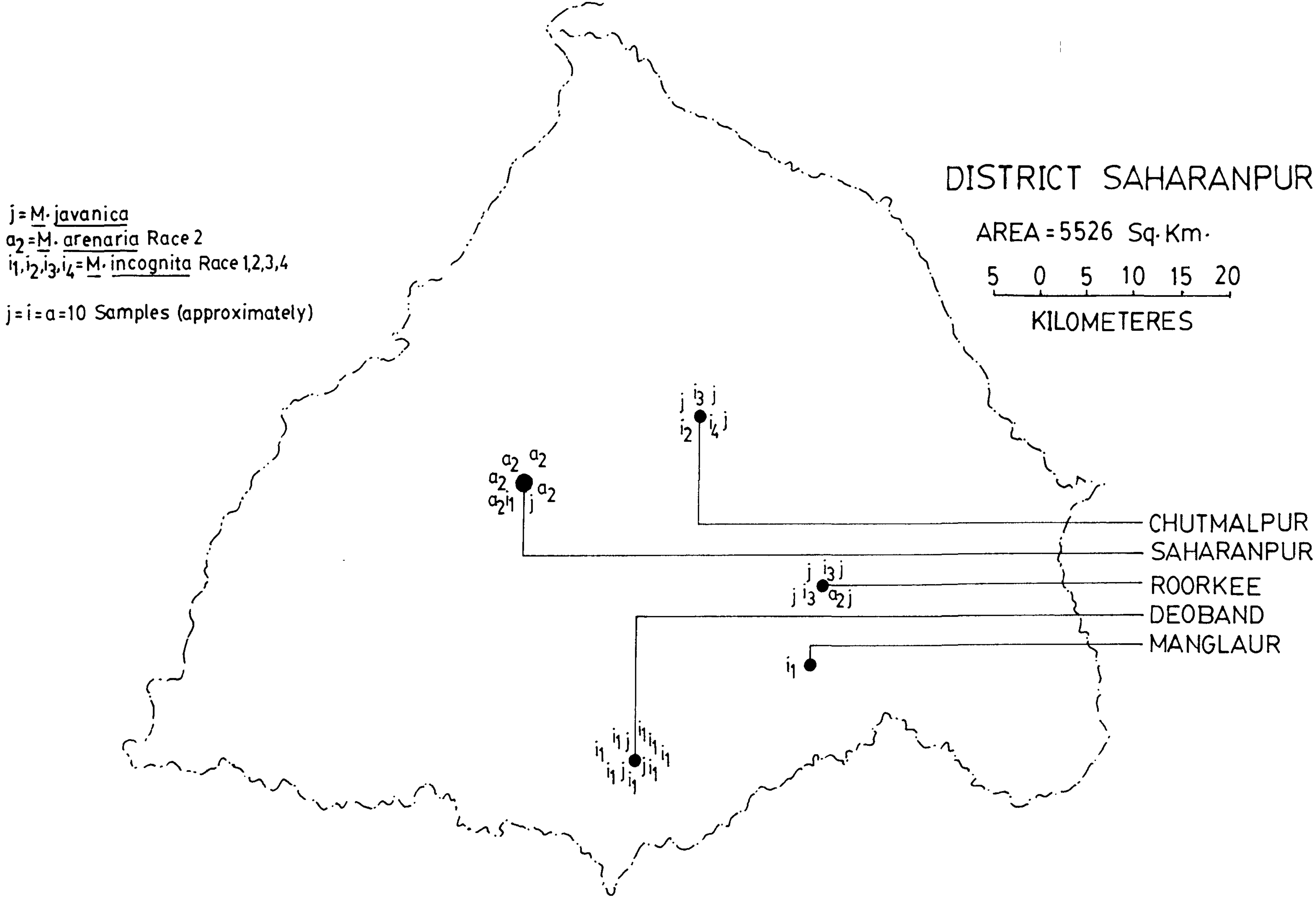


Fig.8: Distribution of root-knot nematodes and their races in district Saharanpur.

Table 37. Incidence and intensity of root-knot nematodes on vegetable crops in district localities of Saharanpur district.

Locality	Incidence						Intensity
	No. of cultivation units			No. of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Saharanpur city area	15	10	66.66	130	61	46.92	3-5/3-5
Manglaur	7	2	28.57	80	11	13.75	4/4
Deoband	18	16	88.88	180	91	50.55	3-5/0-5
Roorkee	14	7	50.00	140	36	25.71	3-5/2-5
Chutmalpur	17	7	41.17	149	37	23.27	3-5/2-5

GI = Gall index; EMI = Eggmass index

Intensity of disease on eggplant, tomato and pepper was from moderate to very severe. GI/EMI on these crops were 3-5/3-5. On rest of the vegetables,GI/EMI range was 3-5/0-5 (Table 38).

Identity and frequency of root-knot nematode species :

a. Identity of the species :-

Three species of root-knot nematodes viz., *M. incognita*, *M. javanica*, and *M. arenaria* were recorded from the district (Fig.8, Table 39). In single populations, *M. incognita* and *M. javanica* were found in all the localities except Saharanpur city area and Manglaur respectively. *M. arenaria* in single population was found only in Saharanpur city area.

b. Frequency of the species in single and mixed populations :-

In single population, frequency of *M. arenaria* was much greater than *M. javanica* in Saharanpur city area. In Manglaur, only *M. incognita* was recorded. Therefore, its frequency was 100%. Frequency of *M. incognita* was greater than *M. javanica* in Deoband. However, in Roorkee and Chutmalpur, frequency of *M. javanica* was greater than *M. incognita* (Table 39).

Among the localities, highest frequency of *M. incognita* was observed in Deoband (75.90%). In rest of the localities where it was encountered, its frequency range was from 2.40% to 13.25%. Highest frequency of *M. javanica* was noticed in Roorkee

Table 38. Incidence and intensity of root-knot nematodes on different vegetable crops in Saharanpur district.

Crop	Incidence						Intensity
	No.of cultivation units			No.of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Eggplant	14	13	92.85	140	63	45.00	3-5/3-5
Tomato	5	4	80.00	50	35	70.00	3-5/3-5
Pepper	20	9	45.00	192	37	19.27	3-5/3-5
Okra	11	5	45.00	100	37	37.00	4-5/0-5
Cucumber	9	9	100.00	90	56	62.22	3-5/2-5
Cauliflower	10	2	20.00	100	8	8.00	3-4/3-4
Cabbage	2	-	-	17	-	-	-

GI = Gall index; EMI = Eggmass index

followed by in Deoband, Chutmalpur and Saharanpur city area. *M. arenaria* was recorded only from Saharanpur city area in single population. Therefore, its frequency was 100% (Table 39).

Mixed infections of the two or all of the three species were also recorded. In Saharanpur city area, frequencies of *M. incognita* and *M. javanica*; *M. incognita* and *M. arenaria*; and *M. javanica* and *M. arenaria* combinations were very low being 8.19%; 11.47%; and 4.91% respectively. In Deoband and Chutmalpur, only *M. incognita* and *M. javanica* combination was recorded with 16.48% and 51.35% frequencies respectively. In Roorkee, frequency of combination of all three species was greater than *M. incognita* and *M. javanica*; and *M. javanica* and *M. arenaria* combinations (Table 39).

Among the localities, frequency of mixed populations of *M. incognita* and *M. javanica* was greater in Chutmalpur than in other localities. Mixed populations of *M. incognita* and *M. arenaria* was found only in Saharanpur city area and of all the three species together only in Roorkee. Consequently, their frequencies were 100%. Combination of *M. javanica* and *M. arenaria* in mixed population was recorded from two localities, Saharanpur city area and Roorkee with equal frequency (50%) in each locality (Table 39).

c. Frequency of the species in total infected samples :-

In total infected samples, *M. arenaria* was most frequent in Saharanpur city area. Its frequency was greater than

Table 39. Frequency of occurrence of species (%) of root-knot nematodes in single and mixed populations on vegetable crops in different localities of Saharanpur district.

Locality	Frequency of species						
	Single population			Mixed population			
	Mi	Mj	Ma	Mi+Mj	Mi+Ma	Mj+Ma	Mi+Mj+Ma
Saharanpur city area	-	8.19* (11.36)**	67.21 (100.00)	8.19 (10.86)	11.47 (100.00)	4.91 (50.00)	-
Manglaur	100.00 (13.25)	-	-	-	-	-	-
Deoband	69.23 (75.90)	14.28 (29.54)	-	16.48 (32.60)	-	-	-
Roorkee	5.55 (2.40)	41.66 (34.09)	-	19.44 (15.21)	-	8.33 (50.00)	25.00 (100.00)
Chutmalpur	18.91 (8.43)	29.72 (25.00)	-	51.35 (41.30)	-	-	-

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria*

M. javanica or M. incognita. However, in Roorkee frequency of M. javanica was greater than M. incognita or M. arenaria. From Manglaur, only M. incognita was recorded. In Deoband M. incognita was more frequent than M. javanica but in Chutmalpur M. javanica than M. incognita (Table 40).

Among the localities, frequency of M. incognita was more in Deoband than in Chutmalpur, Roorkee, Saharanpur city area and Manglaur. Frequency of M. javanica was higher in Roorkee than in Chutmalpur, Deoband and Saharanpur city area. M. arenaria was recorded from two localities. Its frequency was greater in Saharanpur than Roorkee (Fig.8, Table 40).

Identity and frequency of the races :

All the four races of M. incognita were recorded from the district (Fig.8, Table 41). But Race 1 of M. incognita was apparently more frequent than others as it was recorded from Saharanpur city area, Manglaur and Deoband with 100% frequency in each. In Roorkee, only Race 3 was found. In Chutmalpur where Race 2, Race 3 and Race 4 were present frequency of Race 4 was greater than Race 2 and Race 3 (Table 41),

Among the localities, frequency of Race 1 was higher in Deoband than Saharanpur city area and Manglaur. Race 2 and Race 4 were present only in Chutmalpur. Consequently, frequency of each was 100%. Frequency of Race 3 was greater in Roorkee than Chutmalpur (10%) (Table 41).

Race 2 was identified to be present in M. arenaria populations. Its frequency was greater in Saharanpur city area (80.95%) than Roorkee (19.04%) (Fig.8, Table 41).

Table 40. Frequency of occurrence of species (%) of root-knot nematodes in different localities of Saharanpur district based on total infected root samples of vegetables.

Locality	Total infected root samples	No.of root samples infected (single + mixed populations)			Frequency of species in total infected samples		
		Mi	Mj	Ma	Mi	Mj	Ma
Saharanpur city area	61	12	13	51	19.67* (8.27)**	21.31 (12.38)	83.60 (80.95)
Manglaur	11	11	-	-	100.00 (7.58)	-	-
Deoband	91	78	28	-	85.71 (53.79)	30.76 (26.66)	-
Roorkee	36	18	34	12	50.00 (12.41)	94.44 (32.38)	33.33 (19.04)
Chutmalpur	37	26	30	-	70.27 (17.93)	81.08 (28.57)	-

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = <u>M</u>. <u>incognita</u>; Mj = <u>M</u>. <u>javanica</u>; Ma = <u>M</u>. <u>arenaria</u>

Table 41. Frequency of occurrence of races of *Meloidogyne incognita* (Mi) and *Meloidogyne arenaria* (Ma) in different localities of Saharanpur district.

Locality	Species/Races	Frequency (%) of races of Mi				Frequency(%) of races of Ma	
		R_1	R_2	R_3	R_4	R_1	R_2
Saharanpur city area	MaR_2, MiR_1	100.00* (11.88)**	-	-	-	-	100.00 (80.95)
Manglaur	MiR_1	100.00 (10.89)	-	-	-	-	-
Deoband	MiR_1	100.00 (77.22)	-	-	-	-	-
Roorkee	MaR_2, MiR_3	-	-	100.00 (90.00)	-	-	100.00 (19.04)
Chutmalpur	MiR_2, MiR_3, MiR_4	-	26.00 (100.00)	7.69 (10.00)	65.38 (100.00)	-	-

* Values in rows represent frequency (%) of the races in the same locality.

** Values in parentheses in the columns of the races represent frequency (%) of the race in different localities.

Mi = *M. incognita*; Ma = *M. arenaria*

R_1 = Race 1, R_2 = Race 2, R_3 = Race 3 and R_4 = Race 4

7. DEHRADUN

Incidence and intensity of the disease :

Five localities viz., Dehradun city area, Mussoorie, Rishikesh, Chakrata and Tinni were selected for survey in Dehradun district (Fig.9). Root samples were collected from Dehradun, Mussoorie and Rishikesh but not from Chakrata and Tinni since no vegetable cultivation was found in these two localities during the survey. Incidence of the disease was 59.25% and 75% in vegetable fields of Dehradun city area and Mussoorie respectively. No disease was found in vegetable fields of Rishikesh. In root samples, frequency of the disease was more or less equal in Dehradun city area (33.73%) and Mussoorie (32.50%) (Table 42).

Intensity of disease in Dehradun city area was moderate to very severe. The GI/EMI range was 3-5/3-5. In Mussoorie, GI was 3-5 indicating moderate to very severe disease intensity but EMI range was 2-5 (Table 42).

Among the vegetables, incidence of the disease was considerably high in cabbage, cauliflower and tomato fields. In eggplant, pepper and okra fields, incidence was comparatively low. A solitary cultivation unit of cucumber found during survey, was free from infection (Table 43).

On root sample basis, incidence of the disease on different vegetables did not differ much. It was 43.33%, 40%, 30.66%, 30%,

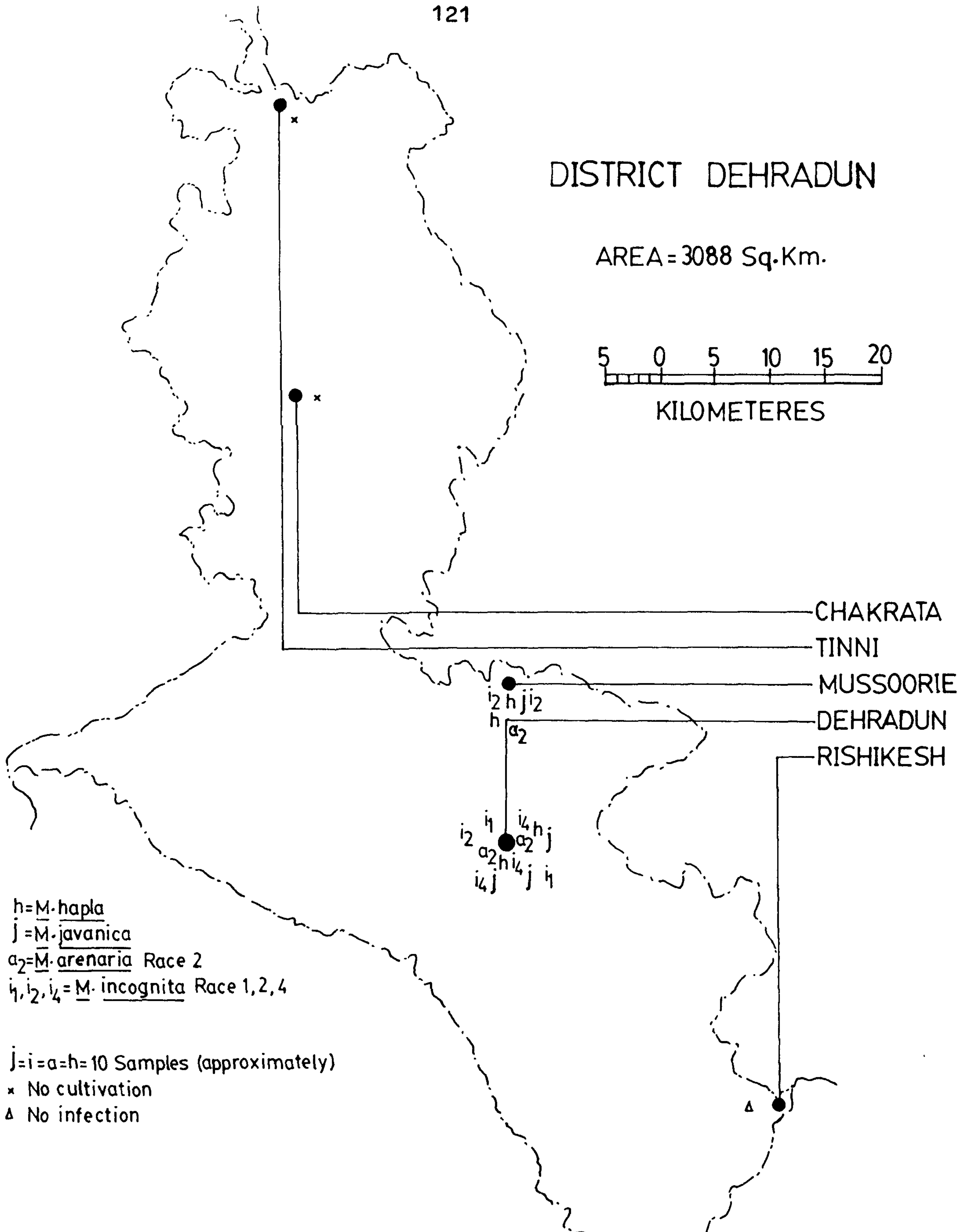


Fig.9: Distribution of root-knot nematodes and their races in district Dehradun.

Table 42. Incidence and intensity of root-knot nematodes on vegetable crops in different localities of Dehradun district.

Locality	Incidence						Intensity
	No.of cultivation units			No. of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Dehradun city area	27	16	59.25	249	84	33.73	3-5/3-5
Mussoorie	8	6	75.00	80	26	32.50	3-5/2-5
Rishikesh	2	-	0.00	20	-	0.00	-
Chakrata	No cultivation of vegetable crops						
Tinni	No cultivation of vegetable crops						

GI = Gall index; EMI = Eggmass index

Table 43. Incidence and intensity of root-knot nematodes on different vegetable crops in Dehradun district.

Crop	Incidence						Intensity
	No.of cultivation units			No.of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Eggplant	8	4	50.00	75	23	30.66	3-5/3-5
Tomato	5	4	80.00	45	18	40.00	3-5/3-5
Pepper	7	3	42.85	62	17	27.41	4-5/3-5
Okra	5	2	40.00	47	11	23.40	5/5
Cucumber	1	-	-	10	-	0.00	-
Cauliflower	5	4	80.00	50	15	30.00	3-5/2-5
Cabbage	6	5	83.33	60	26	43.33	3-5/2-5

GI = Gall index; EMI = Eggmass index

27.41% and 23.40% on cabbage, tomato, eggplant, cauliflower, pepper and okra respectively (Table 43).

GI and EMI indicated that intensity of the disease was mild to very severe (Table 43).

Identity and frequency of root-knot nematode species :

a. Identity of the species :-

Four species of root-knot nematodes, *M. incognita*, *M. javanica*, *M. arenaria* and *M. hapla* were recorded from the district (Fig.9, Table 44). *M. incognita*, *M. javanica* and *M. hapla* were present singly or concomitantly. *M. arenaria* was found only in mixed populations. *M. incognita* with *M. javanica*; *M. incognita* with *M. arenaria*; *M. incognita* with *M. hapla*; *M. javanica* with *M. arenaria*, *M. arenaria* with *M. hapla*; *M. incognita*, *M. javanica* with *M. arenaria* were found together in mixed populations (Table 44).

b. Frequency of the species in single and mixed populations:-

In single population, frequency of *M. incognita* was greater than *M. javanica* and *M. hapla* in Dehradun city area. In Mussoorie, only *M. javanica* was present in single population. Between the localities, *M. incognita* and *M. hapla* each showed 1.00% frequency, since both were recorded only from Dehradun city area. Frequency of *M. javanica*, recorded from two localities, was much greater in Dehradun city area than Mussoorie (Table 44).

Table 44. Frequency of occurrence of species (%) of root-knot nematodes in single and mixed populations on vegetable crops in different localities of Dehradun district.

Locality	Frequency of species									
	Single population				Mixed population					
	Mi	Mj	Ma	Mh	Mi+Mj	Mi+Ma	Mi+Mh	Mj+Ma	Ma+Mh	Mi+Mj+Ma
Dehradun city area	28.57* (100.00)**	21.42 (85.71)	-	5.95 (100.00)	7.14 (75.00)	15.47 (100.00)	13.09 (52.38)	-	8.33 (58.33)	-
Mussoorie	-	11.53 (14.28)	-	-	7.69 (25.00)	-	38.46 (47.61)	-	19.23 (41.66)	23.07 (100.00)
Rishikesh	-	-	-	-	-	-	-	-	-	-
Chakrata	No cultivation of vegetable crops									
Tinni	No cultivation of vegetable crops									

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency(%) of the species in different localities.

Mi = *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria*; Mh = *M. hapla*

In mixed populations frequencies were low and ranged between 7.14% and 15.47% in Dehradun city area. In Mussoorie, frequency of *M. incognita* and *M. hapla* combination was higher than the combination of *M. incognita*, *M. javanica* and *M. arenaria* or of *M. arenaria* and *M. hapla* and of *M. incognita* and *M. javanica* (Table 44).

Frequency of *M. incognita* and *M. javanica* was greater in Dehradun city area than Mussoorie. Frequency of mixed populations of *M. incognita* and *M. arenaria*; and of *M. incognita*, *M. javanica* and *M. arenaria* were 100% as they were recorded only from Drhradun city area and Mussoorie respectively. Frequency of *M. incognita* and *M. hapla* combination; and of *M. arenaria* and *M. hapla* combination was greater in Dehradun city area than Mussoorie (Table 44).

c. Frequency of the species in total infected samples :-

M. incognita was more frequent than the other species found in the district. Frequency of *M. incognita* was highest in total infected samples in Dehradun city area followed by *M. javanica*, *M. hapla* and *M. arenaria*. Its frequency was also highest in Mussoorie followed by *M. hapla*. In Mussoorie, frequency of *M. javanica* equalled with *M. arenaria* but was less than other two species (Fig.9, Table 45).

In total infected samples among the localities, frequency of *M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla* was greater in Dehradun city area than Mussoorie (Fig.9, Table 45).

Table 45. Frequency of occurrence of species (%) of root-knot nematodes in different localities of Dehradun district based on total infected root samples of vegetables.

Locality	Total infected root samples	No.of root samples infected (Single + mixed populations)				Frequency of species in total infected samples			
		Mi	Mj	Ma	Mh	Mi	Mj	Ma	Mh
Dehradun city area	84	54	24	20	23	64.28* (75.00)**	28.57 (68.57)	23.80 (64.51)	27.38 (60.52)
Mussoorie	26	18	11	11	15	69.23 (25.00)	42.30 (31.42)	42.30 (35.48)	57.69 (39.57)
Rishikesh	-	-	-	-	-	-	-	-	-
Chakrata	No cultivation of vegetable crops								
Tinni	No cultivation of vegetable crops								

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency(%) of the species in different localities.

Mi = *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria*; Mh = *M. hapla*

Table 46. Frequency of occurrence of races of *Meloidogyne incognita* (Mi) and *Meloidogyne arenaria* (Ma) in different localities of Dehradun district.

Locality	Species/Races	Frequency (%) of races of Mi				Frequency(%) of races of Ma	
		R_1	R_2	R_3	R_4	R_1	R_2
Dehradun city area	MaR_2, MiR_1, MiR_2, MiR_4	29.62* (100.00)**	18.51 (35.71)	-	51.85 (100.00)	-	100.00 (64.51)
Mussoorie	MaR_2, MiR_2	-	100.00 (64.28)	-	-	-	100.00 (35.48)
Rishikesh	-	-	-	-	-	-	-
Chakrata	No cultivation of vegetable crops						
Tinni	No cultivation of vegetable crops						

* Values in rows represent frequency (%) of the races in the same locality.

** Values in parentheses in the columns of the races represent frequency (%) of the race in different localities.

Mi = *M. incognita*; Ma = *M. arenaria*

R_1 = Race 1, R_2 = Race 2, R_3 = Race and R_4 = Race 4

Identity and frequency of the races :

Race 1, Race 2, Race 4 of *M. incognita* and Race 2 of *M. arenaria* were recorded from the district (Fig.9, Table 46). All the three races of *M. incognita* were present in Dehradun city area, but in Mussoorie, only Race 2 was found. In Dehradun city area, frequency of Race 4 was greater than Race 1 and Race 2. However, in Mussoorie only Race 2 was recorded, with 100% frequency (Table 46). Among the localities, frequency of Race 1 and Race 4 was 100% as they were recorded only from Dehradun city area. But frequency of Race 2 recorded in two localities was greater in Mussoorie than in Dehradun city area (Table 46).

Race 2 of *M. arenaria* was recorded from both the localities. Its frequency was greater in Dehradun city area than Mussoorie (Fig.9, Table 46).

8. NAINITAL

Incidence and intensity of the disease

Five localities of Nainital district, Nainital city area, and Bhawali (situated in the hills), Haldwani, Pantnagar and Kichha (situated at the foot-hills in plain) were surveyed (Fig.10). Incidence of the disease in the vegetable fields in general was higher in localities situated in plains at the foot-hills than in the localities situated in the hills. In Haldwani, Pantnagar and Kichha, incidence of the disease was

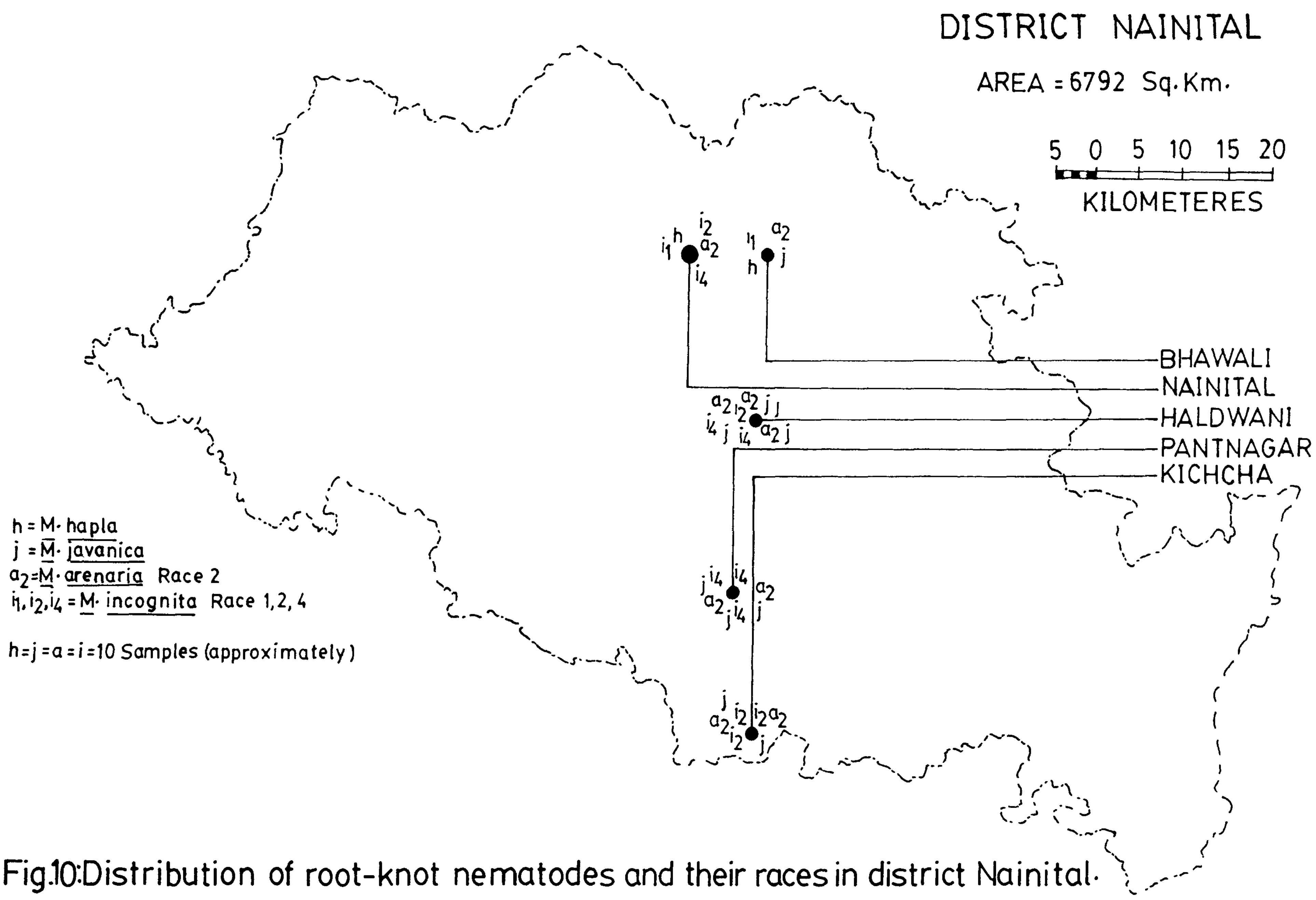


Fig.10: Distribution of root-knot nematodes and their races in district Nainital.

around 60%. In Nainital city area and Bhawali, incidence of the disease was 50% and 42.85% respectively (Table 47). On root sample basis, incidence was highest in Haldwani and Pantnagar followed by Kichcha. Lowest incidence was observed in Bhawali (Table 47).

Intensity of the disease was mild to very severe in the district. Highest intensity of root-knot disease was observed in Pantnagar (4-5/4-5). Intensity of disease was moderate to very severe (3-5/3-5) in Nainital city area and Kichcha; mild to very severe (2-5/2-5) in Haldwani and mild to severe (2-4/2-4) in Bhawali (Table 47).

Incidence of the disease was highest in eggplant fields followed by tomato, okra, pepper and cucumber fields. In both cabbage and cauliflower fields, incidence was 33.33% (Table 48).

On the basis of root samples incidence was highest on eggplant. The incidence on other vegetables ranged between 23.33% and 35.55% (Table 48). The gall indices and eggmass indices ranged was 2-5/2-5 (mild to very severe) on all the vegetables. On cauliflower and cabbage intensity of the disease was low. GI and EMI were 2/2 and 3/3 on cauliflower and cabbage respectively (Table 48).

<u>Identity and frequency of root-knot nematode species</u> :

a. <u>Identity of the species</u> :-

All the four major species of root-knot nematodes: *M. incognita*, *M. javanica*, *M. arenaria* and *M. hapla* were recorded

Table 47. Incidence and intensity of root-knot nematodes on vegetable crops in different localities of Nainital district.

Locality	Incidence						Intensity
	No.of cultivation units			No. of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Nainital city area	12	6	50.00	120	33	27.50	3-5/3-5
Bhawali	7	3	42.85	70	14	20.00	2-4/2-4
Haldwani	18	12	66.66	180	72	40.00	2-5/2-5
Pantnagar	11	7	63.63	110	44	40.00	4-5/4-5
Kichcha	12	7	58.33	120	44	36.66	3-5/3-5

GI = Gall index; EMI = Eggmass index

Table 48. Incidence and intensity of root-knot nematodes on different vegetable crops in Nainital district.

Crop	Incidence						Intensity
	No. of cultivation units			No. of root samples			GI/EMI (Range)
	Surveyed	Infested	Frequency	Collected	Infected	Frequency	
Eggplant	12	10	83.33	120	55	45.83	3-5/3-5
Tomato	14	8	57.14	140	49	35.00	2-5/2-5
Pepper	11	6	54.44	110	30	27.27	3-5/3-5
Okra	9	5	55.55	90	32	35.55	3-5/3-5
Cucumber	8	4	50.00	80	26	32.50	3-5/3-5
Cauliflower	3	1	33.33	30	8	26.66	2/2
Cabbage	3	1	33.33	30	7	23.33	3/3

GI = Gall index; EMI = Eggmass index

from the district (Fig.10, Table 49). In Haldwani, Pantnagar and Kichcha, _M. incognita_, _M. javanica_ and _M. arenaria_ were found. In hilly localities, Nainital city area and Bhawali, _M. hapla_ was also present in addition to the three species. _M. javanica_ was, however, not noticed in Naintal city area. They were found singly or concomitantly in the localities (Table 49).

b. Frequency of the species in single and mixed populations:-

In single populations, no species was found in Nainital city area. In Bhawali only _M. hapla_ was recorded in single populations where its frequency was 21.42%. In Haldwani and Pantnagar, _M. incognita_ and _M. javanica_ were equally frequent. But frequency of _M. incognita_ was greater than _M. arenaria_ in Haldwani and Kichcha (Table 49). Among the localities, _M.incognita_ showed highest frequency in Haldwani closely followed by Kichcha. In Pantnagar, its frequency was low. Frequency of _M. javanica_ was much greater in Haldwani than in Pantnagar. Frequency of _M. arenaria_, was greater in Kichcha than in Haldwani. Since _M. hapla_ in single population was found only in Bhawali, its frequency was 100% (Table 49).

Different combinations of the species were observed in mixed populations. In Nainital city area, in some samples _M. incognita_ and _M. hapla_ were present in mixture whereas in other samples _M. arenaria_ and _M. hapla_ were present together. Frequency of _M. incognita_ and _M. hapla_ combination was greater than M. arenaria and M. hapla. In Bhawali, combination of M. arenaria and M. hapla as well as of M. incognita and M. javanica were found. Frequency of M. arenaria and M. hapla combination was greater than M. incognita and M. javanica. In Haldwani M. incognita and M. arenaria were present together in some samples whereas in some other samples M. javanica and M. arenaria were found together. Frequency of M. javanica and M. arenaria combination was greater than M. incognita and M. arenaria combination. In Pantnagar, four different combinations of the species in mixed populations were observed, as given in Table 49. Highest frequency was shown by M. incognita and M. javanica combination. Frequency of M. incognita and M. arenaria combination was equal to frequency of M. javanica and M. arenaria combination. In three species combination, M. incognita, M. javanica and M. arenaria were observed in Pantnagar with 11.36% frequency. In Kichcha, frequency of M. javanica and M. arenaria combination was higher than M. incognita and M. javanica combination (Table 49).

Among the localities, frequency of M. incognita and M. javanica was higher in Pantnagar than in Kichcha or Bhawali. Frequency of M. incognita and M. arenaria combination, was higher in Pantnagar than in Haldwani. Frequency of M. incognita and M. hapla or M. incognita, M. javanica and M. arenaria combinations were 100% as they were recorded only in one locality i.e. Nainital city area and Pantnagar respectively. Frequency of mixed populations of M. javanica and M. arenaria was higher in Haldwani than

Table 49. Frequency of occurrence of species (%) of root-knot nematodes in single and mixed populations on vegetable crops in different localities of Nainital district.

Locality	Frequency of species									
	Single population				Mixed population					
	Mi	Mj	Ma	Mh	Mi+Mj	Mi+Ma	Mi+Mh	Mj+Ma	Ma+Mh	Mi+Mj+Ma
Nainital city area	-	-	-	-	-	-	75.75* (100.00)**	-	24.24 (50.00)	-
Bhawali	-	-	-	21.42 (100.00)	21.42 (13.63)	-	-	-	57.14 (50.00)	-
Haldwani	30.55 (44.00)	29.16 (75.00)	6.94 (45.45)	-	-	5.55 (40.00)	-	27.77 (54.05)	-	-
Pantnagar	15.92 (14.00)	15.90 (25.00)	-	-	29.54 (59.09)	13.63 (60.00)	-	13.63 (16.21)	-	11.36 (100.00)
Kichcha	47.72 (42.00)	-	13.63 (54.54)	-	13.63 (27.27)	-	-	25.00 (29.72)	-	-

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = _M. incognita_; Mj = _M. javanica_; Ma = _M. arenaria_; Mh = _M. hapla_ in Kichcha and Pantnagar. Frequency of M. arenaria and M. hapla combination was at par in Nainital city area and in Bhawali (Table 49).

c. **Frequency of the species in total infected samples** :-

In localities situated in the hills, frequency of M.hapla was greater than other species. But in localities of plains, M. incognita was more frequent than M. javanica and M. arenaria except in Haldwani where M. javanica dominated. It also equalled with M. incognita in Pantnagar (Table 50). Frequency of M. hapla which was recorded from Nainital city area and Bhawali showed high frequency values in both localities.

Among the localities, frequency of M. incognita ranged between 2.67% and 27.67% in the localities. Frequency of M. javanica was greater in Haldwani than in Pantnagar, Kichcha and Bhawali. Frequency of M. arenaria was greater in Haldwani than in Pantnagar, Kichcha, Nainital city area and Bhawali. Frequency of M. hapla was greater in Nainital city area than in Bhawali (Fig.10, Table 50).

Identity and frequency of the races :

Three races of M. incognita (Race 1, Race 2 and Race 4) and Race 2 of M. arenaria were identified in the samples (Fig.10, Table 51). In Nainital city area, frequency of Race 1 of M. incognita was greater than Race 2 and Race 4. Frequency of Race 4 was greater than Race 2 in Haldwani. In Bhawali,

Table 50. Frequency of occurrence of species (%) of root-knot nematodes in different localities of Nainital district based on total infected root samples of vegetables.

Locality	Total infected root samples	No.of root samples infected (single + mixed populations)				Frequency of species in total infected samples			
		Mi	Mj	Ma	Mh	Mi	Mj	Ma	Mh
Nainital city area	33	25	-	8	33	75.75* (22.32)**	-	24.24 (10.12)	100.00 (75.00)
Bhawali	14	3	3	8	11	21.42 (2.67)	21.42 (3.26)	57.14 (10.12)	78.57 (25.00)
Haldwani	72	26	41	29	-	36.11 (23.21)	56.94 (44.56)	40.27 (36.70)	-
Pantnagar	44	31	31	17	-	70.45 (27.67)	70.45 (33.69)	38.63 (21.51)	-
Kichcha	44	27	17	17	-	61.36 (24.10)	38.63 (18.47)	38.63 (21.51)	-

* Values in rows represent frequency (%) of the species in the same locality.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different localities.

Mi = *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria*; Mh = *M. hapla*

Pantnagar and Kichcha only one race of *M. incognita* was recorded. Race 1 was found in Bhawali, Race 4 in Pantnagar and Race 2 in Kichcha. Subsequently, frequencies of these races in the localities of their occurrence was 100% (Table 51).

Among the localities, Race 1 was more frequent in Nainital city area than in Bhawali. Frequency of Race 2 was greater in Kichcha than in Nainital city area and Haldwani. Frequency of Race 4 was greater in Pantnagar than in Haldwani and Nainital city area (Table 51).

In *M. arenaria*, only Race 2 was recorded in all the localities. Subsequently, the frequency was 100% in each locality. Its frequency ranged between 10.12% and 36.70% among the localities of its occurrence (Fig.10, Table 51).

Overall incidence and intensity of the disease in the area :

A comparative assesement of the root-knot nematodes occurring on vegetables in 8 districts of Western Uttar Pradesh i.e. Aligarh, Bulandshahr, Ghaziabad, Meerut, Muzaffarnagar, Saharanpur, Dehradun and Nainital (Fig.2) with respect to incidence and intensity of the disease in the districts or on vegetables, frequency of occurrence of the different species of *Meloidogyne* and races of *M. incognita* and *M. arenaria* indicated that incidence of the disease was highest in Aligarh district. The frequency of occurrence of the disease in cultivation units was 76.47%. In the fields of other districts,

Table 51. Frequency of occurrence of races of *Meloidotyne incognita* (Mi) and *Meloidogyne arenaria* (Ma) in different localities of Nainital district.

Locality	Species/Races	Frequency (%) of races of Mi				Frequency(%) of races of Ma	
		R_1	R_2	R_3	R_4	R_1	R_2
Nainital city area	MaR_2, MiR_1, MiR_2, MiR_4	52.00* (81.25)**	28.00 (18.42)	-	20.00 (8.62)	-	100.00 (10.12)
Bhawali	MaR_2, MiR_1	100.00 (18.75)	-	-	-	-	100.00 (10.12)
Haldwani	MaR_2, MiR_2 MiR_4	-	15.38 (10.52)	-	84.61 (37.93)	-	100.00 (36.70)
Pantnagar	MaR_2, MiR_4	-	-	-	100.00 (53.44)	-	100.00 (21.51)
Kichcha	MaR_2, MiR_2	-	100.00 (71.05)	-	-	-	100.00 (21.51)

* Values in rows represent frequency (%) of the races in the same locality.

** Values in parentheses in the columns of the races represent frequency(%) of the race in different localities.

Mi = *M. incognita*; Ma = *M. arenaria*

R_1 = Race 1, R_2 = Race 2, R_3 = Race 3 and R_4 = Race 4

the frequency of the disease ranged between 49.18% and 64.14%, lowest being in Ghaziabad. The frequency in all the districts except Ghaziabad was more than 50% (Table 52). On the basis of root samples, highest frequency was found on roots from Muzaffarnagar (55.13%) followed by Aligarh (41.26%). In rest of the districts it ranged from 25.75% to 38.34%. In all the districts except Bulandshahr more than 30% root samples of vegetables were infected (Table 52).

Intensity of the diseases on the basis of GI/EMI showed a wide range of variations. It varied from field to field, vegetable to vegetable or even from sample to sample. The intensity of the disease in different fields showed variations in each district. It ranged between moderate to severe based on mean GI/EMI.

Highest incidence of the disease was observed in eggplant fields closely followed by fields of cucumber. More than 80% fields of both the crops were infested with root-knot nematodes. In tomato, pepper and okra fields the incidence of the disease was also above 50%. The incidence of the disease in cabbage and cauliflower fields was rather comparatively low. In both the crops, the incidence of the disease in their fields was slightly below 25% (Table 53). On root sample basis highest frequency was found on cucumber roots followed by eggplant. More than 50% of the root samples of both the crops were infected with root-knot nematodes. The frequency of occurrence of the disease on

Table 52. Incidence and intensity of root-knot nematodes on vegetable crops in 8 districts of Western Uttar Pradesh.

District	Incidence						Intensity	Mean of GI/EMI
	No.of cultivation units			No.of root samples			GI/EMI (Range)	
	Surveyed	Infested	Frequency	Collected	Infected	Frequency		
Aligarh	68	32	76.47	710	293	41.26	2-5/0-5	3.8/3.3
Bulandshahr	65	34	52.30	660	170	25.75	2-5/0-5	3.9/3.6
Ghaziabad	61	30	49.18	607	204	33.60	2-5/0-5	4.1/3.7
Meerut	65	42	64.41	665	255	38.34	2-5/0-5	3.9/3.1
Muzaffarnagar	44	28	63.63	477	263	55.13	3-5/1-5	4.1/3.6
Saharanpur	71	42	59.15	689	236	34.25	3-5/0-5	4.0/3.4
Dehradun	37	22	59.45	349	110	31.51	3-5/2-5	4.2/3.7
Nainital	60	35	58.33	600	207	34.50	2-5/2-5	3.8/3.8
Total	417	285	60.50	4757	1738	36.53	2-5/0-5	3.95/3.15

GI = Gall index; EMI = Eggmass index

tomato, pepper and okra root samples was 37.33%, 28.87% and 43.73% respectively. On cauliflower and cabbage root samples, the frequency of the disease was 12.03% and 10.99% respectively (Table 53).

Intensity of disease on different vegetables in term of gall index and eggmass index (GI/EMI) varied. Variations in intensity levels were noticed in different fields of or in different root samples of the same crop (Table 53).

Identity of the species :

All the four major species of *Meloidogyne* viz., *M. incognita*, *M. javanica*, *M. arenaria* and *M. hapla* were found to be present in the area. *M. incognita*, *M. javanica* and *M. arenaria* were encountered in all the districts. *M. hapla* was, however, found only in Dehradun and Nainital districts (Fig.2, Table 54).

Frequency of the species in different districts :

a. Single population :-

Single populations of *M. incognita* and *M. javanica* were found in all the districts, *M. arenaria* in single population was present only in Ghaziabad, Meerut, Saharanpur and Nainital districts. Single population of *M. hapla* was found only in Dehradun and Nainital districts. *M. incognita* was found most frequently than other species in all the districts except Aligarh and Bulandshahr, where its frequency was slighly lower than

Table 53. Incidence and intensity of root-knot nematodes on different vegetable crops in Western Uttar Pradesh.

Crop	Incidence						Intensity	Mean of GI/EMI
	No. of cultivation units			No.of root samples			GI/EMI (Range)	
	Surveyed	Infested	Frequency	Collected	Infected	Frequency		
Eggplant	100	83	83.00	1017	520	51.13	2-5/0-5	4.3/3.3
Tomato	71	46	64.78	691	258	37.33	2-5/2-5	4.0/3.2
Pepper	111	61	54.95	1136	328	28.87	2-5/0-5	3.9/3.0
Okra	60	38	63.33	599	262	43.73	2-5/0-5	4.2/3.1
Cucumber	46	37	80.43	500	276	55.20	2-5/2-5	4.1/3.9
Cauliflower	45	11	24.44	432	52	12.03	2-5/2-5	3.6/2.7
Cabbage	38	9	23.68	382	42	10.99	2-5/2-5	3.6/2.9
Total	471	285	60.50	4757	1738	36.53	2-5/0-5	3.95/3.15

GI = Gall index; EMI = Eggmass index

M. javanica (Table 54). The per cent occurrence of single populations in the 8 districts was 57.59 (Table 57).

When frequency of occurrence of a species was compared among the districts, it was observed that frequency of *M. incognita* was greater in Muzaffarnagar than in rest of the districts. Among the districts frequency of *M. javanica* in single population was higher in Aligarh than in other districts. Frequency of *M. arenaria* was higher in Saharanpur than in Ghaziabad, Nainital and Meerut. Frequency of *M. hapla* was greater in Dehradun than in Nainital (Table 54).

b. Mixed population :-

In mixed populations, 6 combinations of species were recorded from the area. *M. incognita* mixed with *M. javanica* was present in all the districts. Similarly, it was also found in all the districts in mixture with *M. arenaria*. But with *M. hapla* it was found only in Dehradun and Nainital districts. *M. javanica* which was found mixed with *M. incognita* in all the districts was also present in mixture with *M. arenaria* in all the districts except Ghaziabad and Dehradun. *M. arenaria* mixed with *M. hapla* was found in Dehradun and Nainital districts. Three species combination of *M. incognita*, *M. javanica* and *M. arenaria* in mixed populations was also recorded from all the districts except Bulandshahr and Ghaziabad (Table 54). Frequency of occurrence of mixed populations of *M. incognita* and *M. javanica* was greater than other combinations in Aligarh, Bulandshahr, Ghaziabad, Meerut and Saharanpur districts (Table 54). Frequency of occurrence of mixed populations of *M. incognita* and *M.arenaria* in Muzaffarnagar and of *M. incognita* and *M. hapla* in Dehradun and of *M. javanica* and *M. arenaria* in Nainital was greater than other combinations (Table 54). The per cent occurrence of mixed populations was 42.40 in the districts (Fig.11, Table 57).

When frequency of mixed populations of different species were compared among the districts, frequency of occurrence of mixed populations of *M. incognita* and *M. javanica* was found highest in Aligarh district followed by Bulandshahr. Frequency of occurrence of mixed populations of *M. incognita* and *M.arenaria* was highest in Muzaffarnagar. Among the two districts, where *M. incognita* was found mixed with *M. hapla*, and *M. arenaria* mixed with *M. hapla*, frequency of these combinations was greater in Nainital than in Dehradun. Frequency of mixed populations of *M. javanica* and *M. arenaria* was highest in Nainital. Frequency of mixed populations of *M. incognita*, *M. javanica* and *M. arenaria* was highest in Meerut (52%) (Table 54).

Frequency of the species in total infected root samples :

In total infected samples regardless of single or mixed populations species showed variations in their frequency in different districts. *M. incognita*, *M. javanica* and *M. arenaria* were recorded from all the districts. Frequency of *M. incognita* was greater than *M. javanica* in all the districts except Bulandshahr. In Bulandshahr frequency of *M. javanica* was greater

Table 54. Frequency of occurrence of species (%) of root-knot nematodes in single and mixed populations on vegetable crops in districts of Western Uttar Pradesh.

District	Frequency of species									
	Single population				Mixed population					
	Mi	Mj	Ma	Mh	Mi+Mj	Mi+Ma	Mj+Mh	Mj+Ma	Ma+Mh	Mi+Mj+Ma
Aligarh	21.84* (10.11)**	23.54 (25.36)	-	-	40.61 (35.31)	9.55 (16.96)	-	1.70 (5.81)	-	2.73 (10.66)
Bulandshahr	27.64 (7.42)	31.17 (19.48)	-	-	36.47 (18.39)	0.58 (0.60)	-	4.11 (8.13)	-	-
Ghaziabad	61.76 (19.90)	10.29 (7.72)	15.19 (35.22)	-	9.31 (5.63)	3.43 (4.24)	-	-	-	-
Meerut	38.43 (15.48)	12.15 (11.39)	1.96 (5.68)	-	17.25 (13.05)	8.23 (12.72)	-	6.66 (19.76)	-	15.29 (52.00)
Muzaffarnagar	53.16 (22.27)	1.90 (1.83)	-	-	6.46 (5.04)	29.65 (47.27)	-	5.32 (16.27)	-	3.04 (10.66)
Saharanpur	35.16 (13.11)	18.64 (16.17)	17.37 (46.59)	-	19.49 (13.64)	2.96 (4.24)	-	2.54 (6.97)	-	3.81 (12.00)
Dehradun	21.81 (3.79)	19.09 (7.72)	-	4.54 (62.50)	7.27 (2.37)	11.81 (7.87)	19.09 (45.65)	-	10.90 (42.85)	5.45 (8.00)
Nainital	24.15 (7.89)	13.52 (10.29)	5.31 (12.50)	1.44 (37.50)	10.62 (6.52)	4.83 (6.06)	12.07 (54.34)	17.87 (43.02)	7.72 (57.14)	2.41 (6.66)

* Values in rows represent frequency (%) of the species in the same district.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different districts.
Mi = *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria*; Mh = *M. hapla*

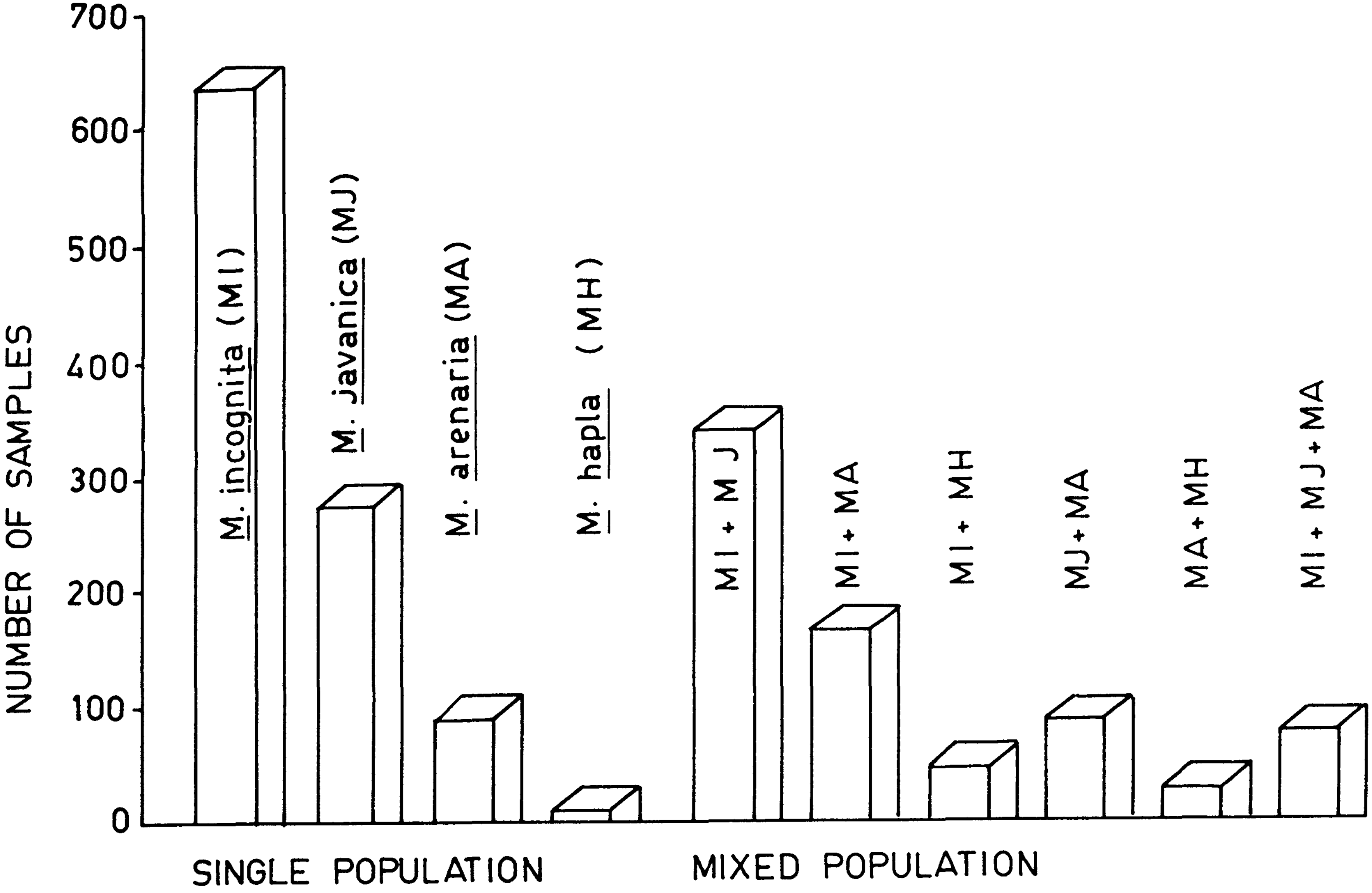


Fig.11: RATIO OF OCCURRENCE OF ROOT-KNOT NEMATODES IN SINGLE AND MIXED POPULATIONS IN ROOT SAMPLES FROM EIGHT DISTRICTS OF WESTERN UTTAR PRADESH

than *M. incognita* and *M. arenaria*. Frequency of *M. arenaria* was lower than of *M. incognita* and *M. javanica* in all the districts except in Muzaffarnagar where its frequency was greater than *M. javanica* (Table 55). *M. hapla* was found only in Dehradun and Nainital. Its frequency was greater than *M. javanica* and *M. arenaria* but lower than *M. incognita* in Dehradun. However, in Nainital, its frequency was lower than the other species (Table 55). The per cent occurrence of the species of root-knot nematodes in the districts is given in Table 58 and Fig.12. It was highest for *M. incognita*.

Among the districts, frequency of *M. incognita* in total infected samples was highest in Muzaffarnagar followed by Aligarh, Meerut, Ghaziabad, Saharanpur, Nainital, Bulandshahr and Dehradun in this order. Frequency of *M. javanica* was highest in Aligarh followed by Meerut, Bulandshahr, Saharanpur, Nainital, Muzaffarnagar, Ghaziabad and Dehradun in this order. Frequency of *M. arenaria* was highest in Muzaffarnagar district followed by Meerut, Nainital, Saharanpur, Aligarh, Ghaziabad, Dehradun and Bulandshahr. Between the districts frequency of *M. hapla* was greater in Nainital than in Dehradun (Table 5').

Identity and frequency of the races :

All the four races of *M. incognita* viz., Race 1, Race 2, Race 3 and Race 4, and Race 2 of *M. arenaria* were recorded from the area included in the study. Race 1, Race 2 and Race 4 of *M. incognita* were found in all the districts. Race 3 was also

Table 55. Frequency of occurrence of species (%) of root-knot nematodes in different districts of Western Uttar Pradesh based on total infected root samples of vegetables.

District	Total infected root samples	No.of root samples infected (single + mixed populations)				Frequency of species in total infected samples			
		Mi	Mj	Ma	Mh	Mi	Mj	Ma	Mh
Aligarh	293	219	201	41	-	74.74* (17.43)**	68.60 (26.10)	13.99 (9.27)	-
Bulandshahr	170	110	122	8	-	64.70 (8.75)	71.76 (15.84)	4.70 (1.80)	-
Ghaziabad	204	152	40	38	-	74.50 (12.10)	19.60 (5.19)	18.62 (8.59)	-
Meerut	255	202	131	82	-	79.21 (16.08)	51.37 (17.01)	32.15 (18.55)	-
Muzaffarnagar	263	244	44	100	-	92.77 (19.42)	16.73 (5.71)	38.02 (22.62)	-
Saharanpur	236	145	105	63	-	61.44 (11.54)	44.49 (13.63)	26.69 (14.25)	-
Dehradun	110	72	35	31	38	65.45 (5.73)	31.81 (4.54)	28.18 (7.01)	34.54 (46.34)
Nainital	207	112	92	79	44	54.10 (8.91)	44.44 (11.94)	38.16 (17.87)	21.25 (53.65)

* Values in rows represent frequency (%) of the species in the same district.

** Values in parentheses in columns of all the species represent frequency (%) of the species in different districts.

Mi = *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria*; Mh = *M. hapla*

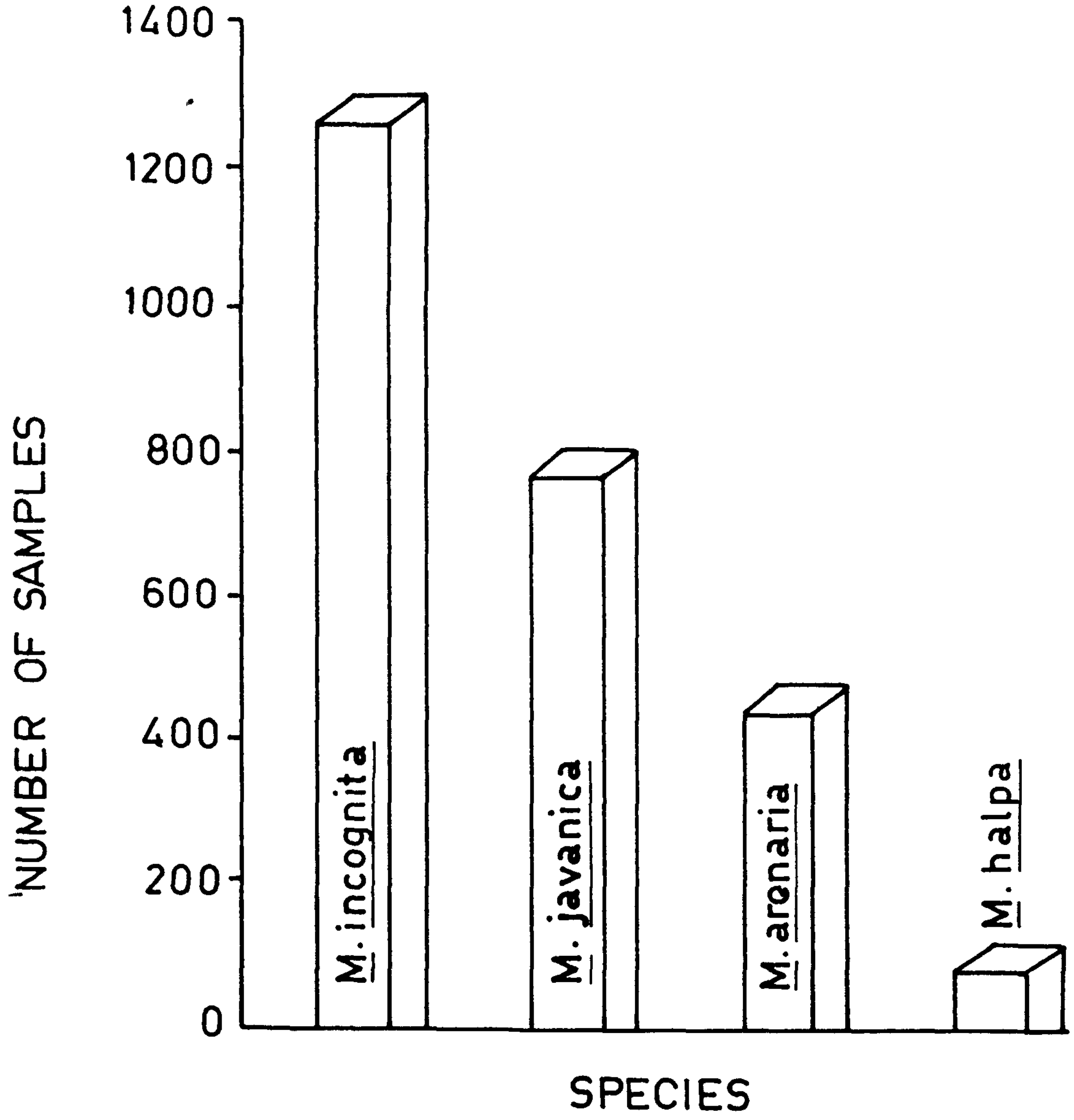


Fig. 12: RATIO OF SPECIES OF MELOIDOGYNE IN TOTAL INFECTED ROOT SAMPLES FROM EIGHT DISTRICTS OF WESTERN UTTAR PRADESH

Table 56. Frequency of occurrence of races of *Meloidogyne incognita* (Mi) and *Meloidogyne arenaria* (Ma) in different districts of Western Uttar Pradesh.

District	Species/Races	Frequency(%) of races of Mi				Frequency(%) of races of Ma	
		R_1	R_2	R_3	R_4	R_1	R_2
Aligarh	MaR_2, MiR_1, MiR_2 MiR_3, MiR_4	37.44* (18.85)**	30.13 (19.70)	15.98 (15.76)	16.43 (13.63)	-	100.00 (9.27)
Bulandshahr	MaR_2, MiR_1, MiR_2, MiR_3, MiR_4	38.18 (9.65)	16.36 (5.37)	38.18 (18.91)	7.27 (3.03)	-	100.00 (1.80)
Ghaziabad	MaR_2, MiR_1, MiR_2, MiR_3, MiR_4	45.39 (15.86)	13.81 (6.26)	6.57 (4.50)	34.21 (19.69)	-	100.00 (8.59)
Meerut	MaR_2, MiR_1, MiR_2, MiR_3, MiR_4	22.77 (10.57)	26.23 (15.82)	22.27 (20.27)	28.71 (21.96)	-	100.00 (18.55)
Muzaffarnagar	MaR_2, MiR_1, MiR_2, MiR_3, MiR_4	25.81 (14.48)	42.62 (31.04)	28.68 (31.53)	2.86 (2.65)	-	100.00 (22.62)
Saharanpur	MaR_2, MiR_1, MiR_2, MiR_3, MiR_4	69.65 (23.21)	4.82 (2.08)	13.79 (9.00)	11.72 (6.43)	-	100.00 (14.25)
Dehradun	MaR_2, MiR_1, MiR_2, MiR_4	22.22 (3.67)	38.88 (8.35)	-	38.88 (10.60)	-	100.00 (7.01)
Nainital	MaR_2, MiR_1, MiR_2, MiR_4	14.28 (3.67)	33.92 (11.34)	-	51.78 (21.96)	-	100.00 (17.82)

* Values in rows represent frequency (%) of the races in the same district.

** Values in parentheses in the columns of the races represent frequency (%) of the race in different districts.

Mi = *M. incognita*; Ma = *M. arenaria*

R_1 = Race 1, R_2 = Race 2, R_3 = Race 3 and R_4 = Race 4

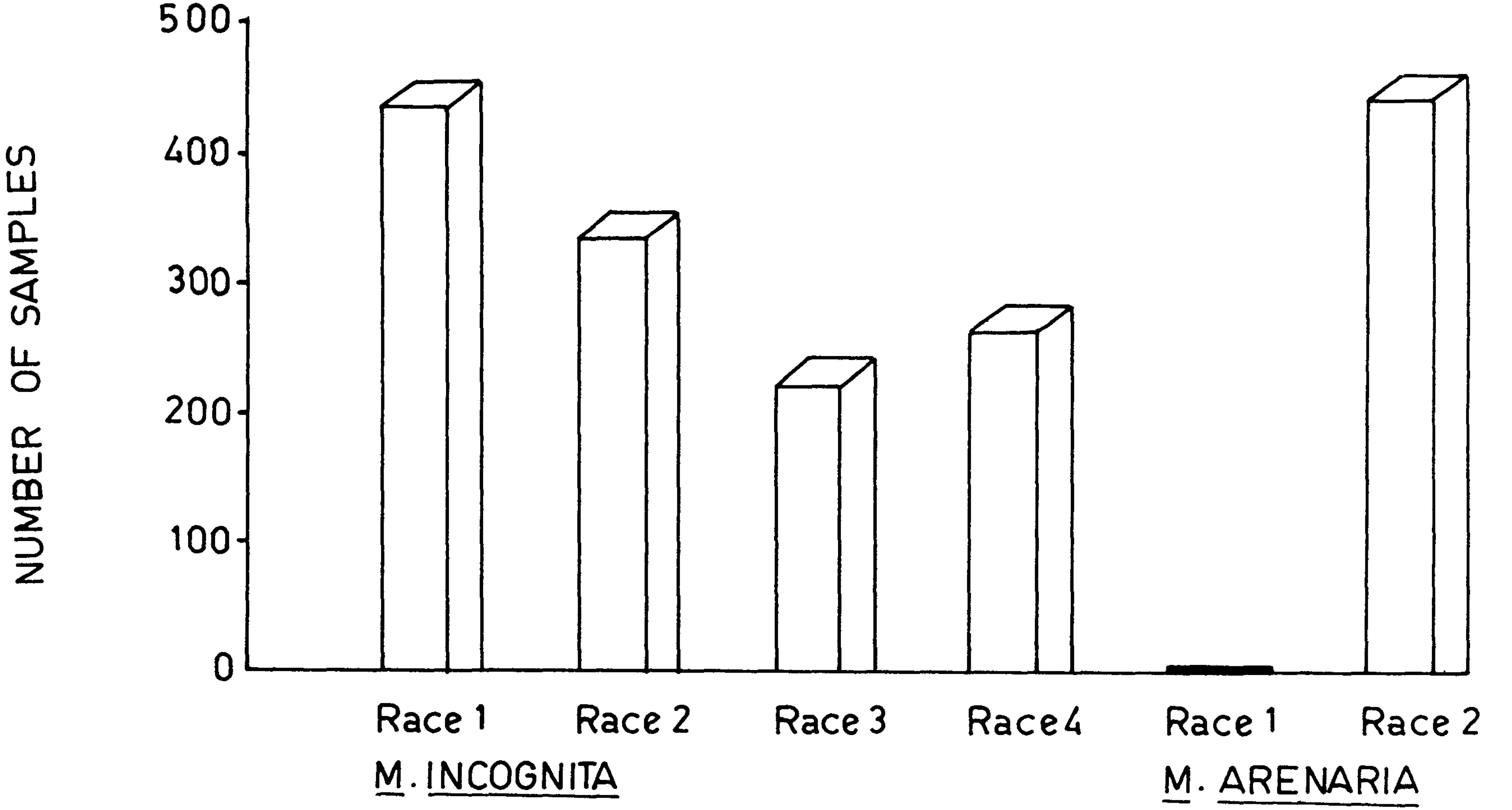


Fig.13: RATIO OF RACES OF M. INCOGNITA AND M. ARENARIA IN ROOT SAMPLES FROM EIGHT DISTRICTS OF WESTERN UTTAR PRADESH.

Table 57. Per cent occurrence of root-knot nematodes in single and mixed populations in 8 districts of Western Uttar Pradesh.

Population of Meloidogyne species	Total number of samples with infection	Total number of samples with single or mixed population	No. of samples with the species	Per cent occurrence
	1738			
Single population		1001		57.59
M. incognita			633	36.42
M. javanica			272	15.65
M. arenaria			88	5.06
M. hapla			8	0.46
Mixed population		737		42.40
Mi + Mj			337	19.39
Mi + Ma			165	9.49
Mi + Mh			46	2.64
Mj + Ma			86	4.94
Ma + Mh			28	1.61
Mi+Mj+Ma			75	4.31

Mi = *M. incognita*; Mj = *M. javanica*; Ma = *M. arenaria*; Mh = *M. hapla*

Table 58. Per cent occurrence of root-knot nematodes in total infected samples in 8 districts of Western Uttar Pradesh.

Meloidogyne species	Total number of samples infected with *Meloidogyne* species	No.of samples with the species	Per cent occurrence of the species
M. incognita	1738	1256	72.26
M. javanica		770	44.30
M. arenaria		442	25.43
M. hapla		82	4.71

Note: In calculation of per cent occurrence both single and mixed populations of species in the samples have been included.

Table 59. Per cent occurrence of races of *Meloidogyne incognita* and *M. arenaria* in 8 districts of Western Uttar Pradesh

Races of *Meloidogyne*	Total number of root samples infected with *Meloidogyne* species	No.of sample with the race	Per cent occurrence of the race
M. incognita	1256		
Race 1		435	34.63
Race 2		335	26.67
Race 3		222	17.69
Race 4		264	21.01
M. arenaria	442		
Race 1		Nil	Nil
Race 2		442	100

present in all the districts except Dehradun and Nainital. Frequency of Race 1 of M. incognita was greater than Race 2, Race 3 and Race 4, in Aligarh, Bulandshahr, Ghaziabad and Saharanpur. In Bulandshahr, frequency of Race 1 was, however, equal to frequency of Race 3. Frequency of Race 4 was greater than other races of M. incognita in Meerut, Dehradun and Nainital. However, in Dehradun, frequency of Race 4 was equal to frequency of Race 2. In Muzaffarnagar frequency of Race 2 was greater than other races of M. incognita (Table 56). The per cent occurrence of races of M. incognita in the districts is given in Table 59 and Fig.13, Race 1 was most frequent.

Among the districts frequency of Race 1 was highest in Saharanpur followed by Aligarh, Ghaziabad, Muzaffarnagar, Meerut, Bulandshahr, Dehradun and Nainital. Frequency of Race 2 was highest in Muzaffarnagar followed by Aligarh, Meerut, Nainital, Dehradun, Ghaziabad, Bulandshahr and Saharanpur. Frequency of Race 3 was highest in Muzaffarnagar followed by Meerut, Bulandshahr, Aligarh, Saharanpur and Ghaziabad in this order. Frequency of Race 4 was highest in Meerut and Nainital, followed by Ghaziabad, Aligarh, Dehradun, Saharanpur, Bulandshahr and Muzaffarnagar in this order (Table 56).

Race 2 of M. arenaria was identified to be present in the area surveyed. Its frequency was highest in Muzaffarnagar followed by Meerut, Nainital, Saharanpur, Aligarh, Ghaziabad, Dehradun and Bulandshahr (Table 56).

DISCUSSION

Meloidogyne incognita, *M. javanica*, *M. arenaria* and *M. hapla* are recognized as major species of root-knot nematodes because of their world-wide distribution and agricultural importance. They attack an array of crops grown in different parts of world and cause substantial damage (Sasser, 1980; Taylor *et al.*, 1982). The findings of present study showed that incidence of the root-knot disease on vegetables (Tables 13,18, 23, 28, 33, 38, 43, 48) was relatively high in the area. With variations in some specific localities, more than 50% cultivation units in each district were infested with root-knot nematodes (Tables 12, 17, 22, 27, 32, 37, 42, 47). The overall incidence of disease in vegetable fields in the entire area was slightly above 60%. On root sample basis, the incidence of disease was above 25% in each district and overall incidence in entire area was above 35% (Table 52). The intensity of the disease was also high. The GI and EMI means were more than 3 in each district. District or locality-wise variations in incidence and intensity of the disease were, however, noticed. In some localities as much as 100% fields were infested. Apparently root-knot nematodes are fairly widely distributed in the area and are infesting a high percentage of vegetable fields. In such fields, fairly good percentage of plants of the vegetables suffer from the disease. Sufficient root galling and egg mass production recorded on crops adversely affect crop productivity and ensure high population build-up which may endanger the ensing crops.

Incidence of the disease was also fairly high on vegetable crops. More than 50 per cent cultivation units of each vegetable crop except cabbage and cauliflower were infested (Table 53). The overall incidence of the disease in cultivation units of each vegetable was above 60%. The disease incidence and intensity were also high in cultivation units of each vegetable except cabbage and cauliflower. Overall incidence of disease on root sample basis was above 35% (Table 53). Some variations from district to district or locality to locality were, however, found (Table 13, 18, 23, 28, 33, 38, 43, 48). Incidence of the disease was highest on eggplant followed by cucumber, tomato, okra and pepper. The root galling and eggmass production was also greater on these crops. Lowest incidence, root galling and eggmass production were found on cabbage and cauliflower. Seemingly vegetable crops in the area, in general, are suffering greatly due to root-knot nematodes. Eggplant, cucumber, tomato, okra and pepper are highly affected crops. Cauliflower and cabbage are apparently less affected.

Vegetables are recognised as most commonly attacked group of crops by root-knot nematodes. The importance of root-knot nematodes as major pathogens of vegetables and other crops under different climatic conditions was reviewed by Franklin (1979), Sasser (1979) and Lamberti (1979). While reviewing their significance under cool temperatre climates Franklin (1979) stated that since a wide and diverse area comes under temperate climates of world, the crops affected may necessarily vary in kind and relative value and economic losses depend not only on severity of the nematode attack but also on the cash value of the crop. She reviewed the root-knot damage to crops such as tomato, cucumber, carrots,potatoes, lettuce, celery, brassicas, legumes and several other plants in different countries of Europe and Pacific particularly caused by the major species of root-knot nematodes. She remarked that compared to the situation in the tropics, damage and crop losses due to root-knot nematodes in cool temperate climates are negligible but very real to the farmer. In isolated instances, fields crops may be completely lost and where conditions favour the nematodes such as on sandy soils and in glasshouses,. serious economic loss occur (Franklin, 1979).

Lamberti (1979) in his review emphasized the economic importance of root-knot nematodes in sub-tropical and Mediterranean climates. He enlisted a number of crops including vegetables that are damage by root-knot nematodes in the Mediterranean region countries like Greece, Yugoslavia, Turkey, Egypt, Algeria and other North African countries. Many vegetable crops belonging to botanical families Solanaceae, Cucurbitaceae, Leguminoseae (=Fabaceae), Liliaceae, Chenopodiaceae, Compositae (=Asteraceae), Umbelliferae (= Apiaceae), Cruciferae (=Brassicaceae) and Malvaceae were claimed to suffer greatly particularly by *M. incognita*.

Sasser (1979) who reviewed the distribution, pathogenicity and relative importance of *Meloidogyne* spp. in the tropics expressed that from the data available there was little doubt that crop losses were very large. In his review, estimated per cent loss due to root-knot nematodes.for vegetables, ranged from 15 to 30%. He remarked that potential for damage caused by root-knot nematodes is ever present in the tropics. Mai (1985) stated that because of root-knot nematodes particularly *M. incognita*, it is very difficult and some times impossible to grow important vegetables such as tomatoes in tropics and semi-tropics.

A number of sporadic reports from some parts in India on vegetable crop damage caused by root-knot nematodes are present. Several of these reports have resulted from artificial inoculation studies (Reddy, 1981; Krishnappa *et al*., 1981). Krishnappa (1985) while reviewing the work done on root-knot nematodes in India indicated that although the disease is most economically important nematode disease on crops plants in India, reports on the estimation of yield lossess have been infrequent, vague and imprecise. Due to lack of systematic studies on distribution of root-knot nematodes and losses caused by them in different parts of the country in crop fields, their real importance is yet be recognised. The present study has clearly demonstrated a high incidence and intensity of disease on major vegetables grown in the area. The wide-spread occurrence of root-knot disease and level of infestations would certainly be reflecting in the productivity of the crops grown in the area. This fact should be taken into account in the disease management strategies of the vegetable crops for the area. It is expected that a comparable situation may emerge in rest part of the State of Uttar Pradesh, other States on the Indo-Gangetic Plains and other areas or States of the country which have such climatic conditions and extensive vegetable cultivations.

All the four major species of root-knot nematodes were found distributed in the area. M. incognita, M. javanica and M. arenaria were present in all the districts (Table 14, 19, 24, 29, 34, 39, 44, 49). M. hapla was restricted to Dehradun and Nainital (Table 44, 49). M. incognita emerged as most frequent species in the area being dominant in all the districts except Bulandshahr where M. javanica was more frequent. Variations in species contents of different localities were, however, found. Such concentrations of a species in specific localities has a significance in crop cultivation in that particular locality in relation to susceptibility of a crop or cultivar to a given species. M. arenaria occupied the third position with respect to relative dominance. In total samples regardless of single or mixed infection collected from all the districts 72.26% root samples were found infected with M. incognita and 44.30% by M. javanica and 25.43% by M. arenaria (Table 58). M. hapla was found only in 4.71% on root samples showing least frequency.

The species were found either singly or in mixed population (Table 54). In single populations also, M. incognita was most frequent followed by M. javanica and M. arenaria in the area. In single population M. hapla was least frequent. Mixed populations of the two species viz., M. incognita with M. javanica, M. incognita with M. arenaria, M. incognita with M. hapla, M. javanica with M. arenaria, M. arenaria with M. hapla or M. incognita, M. javanica and M. arenaria were also found. The frequency of single populations of the species was comparatively higher than of mixed populations (Table 57). Mixed populations of M. incognita and M. javanica were most frequent followed by mixed population of M. incognita and M. arenaria (Table 57). Among the species of root-knot nematodes, the most important species on worldwide basis is unquestionably M. incognita (Sasser, 1980). The frequency and relative importance of major species in tropics have shown that M. incognita constitutes a large portion of root-knot populations. Second position in terms of frequency and relative importance is occupied by M. javanica. It is followed by M. arenaria. M. hapla is infrequent in tropics (Sasser, 1979). M. incognita is also undoubtly the commonest and most wide-spread root-knot nematodes in sub-tropical and Mediterranean climates. In such climates, M. javanica is second most commonest species. M. arenaria is also worldwide in distribution but its local occurrence is less frequent than M. incognita and M. javanica. M. hapla is also found in sub-tropical and Mediterranean climates (Lamberti, 1979). The climatic condition of the area under consideration is sub-tropical and the pattern of distribution and relative dominance of the species obtained are similar as stated by Lamberti (1979) for sub-tropical climates.

A general perusal of information on occurrence of root-knot nematodes in different IMP regions (Tables 1-9) indicates all the four major species were recognised to be present in all the 8 regions except West Africa where M. hapla was absent. Regionwise analysis of occurrence and dominance of the major species of Meloidogyne shows that M. incognita was dominant species in IMP region I (Mexico, Central America, and Caribbean) where it was invariably found in all the countries (Table 2). M. javanica and M. arenaria have also been found in several of the countries of the region. M. hapla was, however, recorded only from Costa Rica (Lopez, 1981), Jamaica (Hutton, 1976,1981) and Mexico (Sosa-Moss, 1982) (Table 2). Similarly M. incognita was present in all the countries of the IMP region II (South America) (Table 3). Apparently it is a dominant species. M. javanica, M. arenaria and M. hapla were also present in several countries of the region. In Brazil in region III (Table 4) all the four major species have been found (Ferraz, 1985). In the region IV (West Africa) M. incognita apparently dominated over M. javanica and M. arenaria which were also quite frequent. M. hapla was however, absent from the region (Table 5). In the region V which included the countries of East Africa (Table 6), M. incognita also dominated over M. javanica and M. arenaria. M. hapla was recorded from Tanzania (Swai, 1981) and Zimbabwe (Martin, 1957, Richardson, 1978) (Table 6). In the region VII (Mediterranean and the Middle East), M. incognita and M. javanica both are dominant species and more frequent than M. arenaria and M. hapla (Table 8).

In the region VI (Asia) (Table 7) M. incognita was predominant species invariably occurring in all the countries. M. javanica was also reported from all the countries. M.arenaria was found to exist in several of them. Occurrence of M.hapla is reported from Japan (Nishizawa, 1981), Korea (Choi, 1981), Pakistan (Maqbool and Saeed, 1981), Philippines (Davide, 1981), Sri Lanka (Sivapalan, 1981), and Taiwan (Wang, 1978). In some of the neighbouring countries of India like Pakistan, Sri Lanka Nepal, Bangladesh and Burma the M. incognita and M. javanica exist. Occurrence of M. arenaria in Bangladesh, Pakistan and Sri Lanka and of M. hapla in Pakistan, and Sri Lanka has been recorded (Chaudhury, 1981; Myint, 1981; Hogger, 1981; Maqbool and Saeed,1981; Sivapalan, 1981).

The pattern of distribution and relative dominance of the root-knot nematode species in the area under consideration of the present study show that in plains M. incognita dominate over the other two species, M. javanica and M. arenaria present in the area. M. hapla is restricted in its distribution being present in the hilly areas. The restricted distribution of M. hapla in the hilly districts, occurring in localities situated above 1967 m. is in accordance to its established relationship with low temperature climates. M. hapla is generally found in areas with annual average temperatures less than 15°C (Sasser and Carter, 1985). It occurs at elevation above 1000 m. (Eisenback et al., 1981)

The occurrence of mixed populations of species in the area particularly in districts located in plains is of great significance and is an important factor for consideration in management programme. *M. incognita*, *M. javanica* and *M. arenaria* have overlapping ecological requirements. They inhabit in areas with average annual temperatures between 15 and 33°C (Sasser and Carter, 1985). Their occurrence in mixed populations is also common in other parts of the world(Taylor *et al*., 1982; Taylor, 1987).

In India, all the 4 major species of *Meloidogyne* have been recorded from one or the other State. *M. incognita* has been reported from the States of Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Delhi, Gujrat, Haryana, Himachal Pradesh, Karnataka, Kashmir, Kerala, Madhya Pradesh, Maharastra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. Existence of *M. javanica* has been recorded in the States of Bihar, Delhi, Haryana, Himachal Pradesh, Kerala, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. Occurrence of *M. arenaria* has been reported from the States of Bihar, Delhi, Tamil Nadu, Uttar Pradesh and West Bengal. *M. hapla* has been recorded from Himachal Pradesh, Tamil Nadu and West Bengal (Table 9).

So far, there has been no report of *M. hapla* from the State of Uttar Pradesh, Its occurrence in some localities of hilly districts of Uttar Pradesh (Dehradun and Nainital) is reported for the first time from the State of Uttar Pradesh.

As indicated in introduction, *M. incognita* was recognised as the species causing the root-knot disease in and around Aligarh is not supported by the present findings. The findings clearly disprove this contention since in Aligarh district *M. incognita*, *M. javanica* and *M. arenaria* are present and the former two are equally frequent. Similarly in most of the other districts, though *M. incognita* is dominant, *M. javanica* is also quite frequent. It has been found dominant over *M. incognita* in Bulandshahr district. The damage potentials of *M. javanica* are similar to *M. incognita*. In view of its damage potentials, wide-spread distribution in the area, the species should not be under-estimated and its importance needs recognition in management programmes of root-knot nematodes. The fact that *M. arenaria* is also more frequently distributed in the area than in other parts of world, should receive attention in management strategies. However, this species is not so recognised potentially damaging as *M. incognita* and *M. javanica* (Lamberti, 1979; Sasser, 1979,1980). The significants of this species in crop damages in the region should be worked out in view of its quite frequent occurrence in the area.

All the four races of *M. incognita* were found in the area under study. Race 1, Race 2, Race 3 and Race 4 were present in all the districts except Dehradun and Nainital wherein Race 3 was not encountered (Tables 5, 6). With variations in specific localities of the districts (Tables 16, 21, 26, 31, 36, 41, 46, 51), Race 1 was most frequent in Aligarh, Bulandshahr, Ghaziabad, Saharanpur and Race 2 was dominant in Muzaffarnagar and Race 4 in Meerut, Dehradun and Nainital. Race 3 encountered only in six districts was less frequent than Race 1 and Race 2 in all the districts except Bulandshahr and Saharanpur. Its frequency was equal to Race 1 in Bulandshahr and more than Race 2 both in Bulandshahr and Saharanpur. Race 4 was more frequent than Race 3 in Aligarh, Ghaziabad, Meerut and less frequent in Bulandshahr, Muzaffarnagar and in Saharanpur. In overall assessment in _M. incognita_ populations, the per cent occurrence of Race 1 was highest followed by Race 2. Race 4 was third most frequent Race. Lowest percentage of occurrence was shown by Race 3 (Table 59). It can be concluded from the results that in the area all the four races of _M. incognita_ with variations in their dominance in specific localities or districts are present. Apparantly, Race 1 is most dominant; Race 2 closely following Race 1 is second in dominance. The other two races (Race 3 and Race 4) are also quite frequent (Table 59). Absence of Race 3 from hilly districts, Dehradun and Nainital might be due to the low temperature conditions which may not be favourable for it. In other parts of the world Race 3 and Race 4 are also comparatively less frequent than Race 1 and Race 2. But Race 3 is apparently more frequent than Race 4 (Tables 2-8).

All the four races of _M. incognita_ have been found in Puerto Rico, Peru, Brazil, Ghana and Egypt. Race 1 is recognised as most important race of _M. incognita_ on worldwide basis (Sasser, 1982). It constituted 72% of _M. incognita_ populations studied under the aeges of IMP. This race has been recorded in all the countries of the IMP regions except Chile, Liberia and Portugal (Tables 2-9). Race 2 is also common in several countries of all the IMP regions except in the countries of the region V (East Africa). Race 3 and Race 4 are equally but less frequent than Race 1 and Race 2 on worldwide basis (Tables 2-9). Among the neighbouring countries of India, Race 1 has been distinguished in M. incognita populations in Pakistan (Maqbool and Saeed, 1981). Bangladesh (Chaudhury, 1981) and Sri Lanka (Sivapalan, 1981). Race 2 in addition to Race 3 and Race 4 have, however, been not recognised in any neighbouring country of India.

In India, with varied climates and different cropping patterns, possibility of variations within populations of M. incognita is great (Krishnappa, 1985). But only a few reports, based on a relatively small number of population studies from 18 States out of 25 in the country, have indicated the occurrence of three races of M. incognita only in six States. Race 1 has been recorded in all the six States viz., Andhra Pradesh, Haryana, Karnataka, Madhya Pradesh, Orissa, and Tamil Nadu (Krishnappa, 1982; Raja and Gill, 1982; Routrary and Das, 1982; Krishnappa and Setty, 1983) (Table 9). Race 2 has been reported from Karnataka (Krishnappa, 1982; Krishnappa and Setty, 1983), Haryana (Raja and Gill, 1982) and Orissa (Routray and Das, 1982), and Race 3 only from Karnataka (Krishnappa and Setty, 1983) (Table 9).

Of the two races known in *M. arenaria* only Race 2 was found in the area under study. With variations in frequency in the localities, it was present in all the districts (Table 16, 21, 26, 31, 36, 41, 46, 51). Highest frequency was observed in Muzaffarnagar followed by Meerut, Nainital, Saharanpur, Aligarh, Ghaziabad, Dehradun and Bulandshahr. Race 1 was not found in any *M. arenaria* population. A perusal of literature also shows that Race 2 is more common than Race 1 in the world. Race 1 which infects peanut occurs in Virginia, North Carolina Georgia, Florida, Alabama, and Texas in U.S.A. and infact this race is responsible for the common name of *M. arenaria* as peanut root-knot nematode (Sasser, 1980). In *M. arenaria* populations studied in different IMP regions, only Race 2 has been recognised except in Egypt and Morocco. In Egypt, only Race 1 and in Morocco both the races of *M. arenaria* have been found to exist (Ibrahim, 1982, 1985). Race 2 has been recorded in Bermuda (Burpee, 1981); Guadeloupe (Anais, 1982); Puerto Rico (Ayala, 1976, 1981); Surinam (Oever, 1982); Bolivia (Taylor *et al.*,1982) Peru (Jatala, 1982); Uruguay (Taylor *et al.*, 1982); Brazil (Ferraz, 1985); Ivory Coast (Fortuner, 1981); Fiji Island (Taylor *et al.*, 1982); Korea (Choi, 1981); Iran (Mojtahadi,1982); Italy (Di Vito and Greco, 1982); Morocco (Ammati, 1982); Portugal (Santos and Abrantes,1979); and Turkey (Yuksel, 1979). Sasser (1982) also has recognised that Race 2 is more frequent (with 84%) than Race 1 (with 16% only).

In India, no attempt was made earlier to differentiate races in populations of *M. arenaria* in any State. The present study recognizing the occurrence of Race 2 in *M. arenaria* populations in the area of the State of Uttar Pradesh is first of its kind. It is likely that Race 2 may be widely distributed and constituting the larger proportion in *M. arenaria* populations in the country.

SUMMARY

Studies were undertaken to assess the incidence and intensity of root-knot disease and to eetablish the identity of species and races of root-knot nematodes associated with vegetable crops in order to understand their pattern of distribution in Western Uttar Pradesh. Six districts namely Aligarh,Bulandshahr, Ghaziabad, Meerut, Muzaffarnagar and Saharanpur situated in Indo-Gengetic plains and two districts namely Dehradun and Nainital located in hilly tracts of Himalayas were selected as study area. Root samples of vegetables like eggplant, tomato, pepper, okra, cucumber, cauliflower and cabbage were collected from different localities of the districts. Disease incidence and intensity were determined for each district and vegetable crop. Species were identified on the basis of parineal pattern characteristics and North Carolina differential host tests. Races were also differentiated on the basis of North Carolina differential host tests. Frequency of occurrence of different species and races in different localities were calculated as detailed in materials and methods. Results obtained showed that overall incidence of the disease in the area was high. More than 35% root samples of vegetables were infected with root-knot nematodes. In all the eight districts almost 50% fields were infested with root-knot nematodes. The incidence of disease in vegetable fields was highest in Aligarh district (76.47%) and lowest in Ghaziabad (49.18%). On the basis of root samples, the incidence of the disease was highest in Muzaffarnagar (55.13%) and lowest in Bulandshahr (25.75%).

Root-knot infection was observed on all the included vegetables. Cucumber and eggplant were most affected crops. Cauliflower and cabbage were least affected. Among the vegetables, the incidence of the disease was highest in eggplant fields (83%) closely followed by cucumber fields (80.43%). The incidence was low in cauliflower (24.44%) and cabbage (23.68%) fields. On the basis of root samples, the incidence of disease was highest on cucumber (55.20%) followed by eggplant (51.13%). Low frequency values were found on cauliflower (12.03%) and cabbage (10.99%).

Intensity of the disease in different localities of the districts and on different vegetable crops showed wide variations. GI/EMI ranged from 2-5/0-5. In the same field, some infected samples showed poor galling and no eggmass productions while some were heavily galled with high eggmass production.

In all four species of *Meloidogyne* viz., *M. incognita*, *M. javanica*, *M. arenaria*, and *M. hapla* were identified to be present in the area associated with the vegetables. *M. incognita*, *M. javanica* and *M. arenaria* were present in all the districts surveyed whereas distribution of *M. hapla* was restricted to Dehradun and Nainital. *M. hapla* was encountered only in the localities situated at the hills i.e. Mussoorie and Dehradun city area in Dehradun and Bhawali and Nainital city area in Nainital districts. In the both localities of Nainital district, *M. hapla* was more frequent than other species. *M. incognita* was found as dominant species occurring most frequent in the area. Second most frequent species was *M. javanica* followed by *M. arenaria*. *M. hapla* was least frequent being confined to hilly regions of Nainital and Dehradun districts. *M. incognita* was found as most frequent species in all the districts except Bulandshahr where *M. javanica* dominated..

The species were found either singly or in mixed populations. In single population also *M. incognita* was most frequent followed by *M. javanica* and *M. arenaria* in the area. Mixed populations of two species viz., *M. incognita* with *M. javanica*, *M. incognita* with *M. arenaria*, *M. incognita* with *M. hapla*, *M. javanica* with *M. arenaria*, *M. arenaria* with *M. hapla* or *M. incognita*, *M. javanica* and *M. arenaria* were also found. The frequency of single populations of the species was comparatively higher than of mixed populations. Mixed populations of *M. incognita* and *M. javanica* were most frequent followed by mixed populations of *M. incognita* and *M. arenaria*.

All the four races of *M. incognita* and Race 2 of the *M. arenaria* were present in the area. Race 1, Race 2 and Race 4 of *M. incognita* were present in all the districts. Race 3 of *M. incognita* was absent from the hilly districts (Dehradun and Nainital). Race 1 of *M. incognita*, was most prevalent followed by Race 2. Race 3 was least frequent. Race 2 was found invariably in all *M. arenaria* populations in all the districts. Race 1 of *M. arenaria* was, however, not encountered in the area.

With variations in specific localities of the districts, Race 1 of *M. incognita* was most frequent in Aligarh, Bulandshahr, Ghaziabad, Saharanpur but Race 2 was dominant in Muzaffarnagar and Meerut and Race 4 in Dehradun and Nainital. Race 3 was less frequent than Race 1 and Race 2 in all the districts except Bulandshahr and Saharanpur. Its frequency was equal to Race 1 in Bulandshahr and more than Race 2 both in Bulandshahr and Saharanpur. Race 4 was more frequent than Race 3 in Aligarh, Ghaziabad, Meerut, and less frequent in Bulandshahr, Muzaffarnagar and in Saharanpur.

M. arenaria Race 2 was present in all the districts. Its frequency was highest in Muzaffarnagar followed by Meerut, Nainital, Saharanpur, Aligarh, Ghaziabad, Dehradun and Bulandshahr.

SECTION II

INTRODUCTION

Almost all cultivated plants of economic importance are vulnerable to attack by one or the other species or races of root-knot nematodes in different parts of the world (Sasser, 1980). Vegetables rank among the most important groups of cultivated crops in India as they are very important constituents of diet for the vast majority of vegetarian population in the country. Vegetables are also the most favoured host crops for root-knot nematodes. Vegetables like tomato, eggplant, pepper, okra, cucumber, cauliflower, cabbage etc. suffer in India as in other parts of the world due to root-knot disease. According to Sasser (1979) per cent loss for vegetables in tropics ranges between 15 to 30 which is substantial.

Plants resistance is an effective and economical means of reducing losses from root-knot nematodes. The importance of root-knot nematode management through resistance of plants has become further significant in recent years due to certain hazards involved in the use of some nematicides. Moreover, nematicidal application is costly, especially for low value crops. Resistance against root-knot nematodes has been observed or introduced in certain crop cultivars (Fassuliotis, 1979). Kaplan (1982) suggested that prior to release, the cultivar should be carefully studied to determine its level of resistance to parasitism including its response to various types or races and its effect on nematode reproduction. Cultivars of several crops have been screened against root-knot nematodes. In tomato, some cultivars have shown resistance to root-knot nematodes. Fassuliotis (1979) mentioned that in 65 cultivars of tomato, resistance to *M. incognita* and *M. javanica* has been selected or introduced. Malo (1964) found tomato cvs. Florida, Hawalian Cross, Kola-C, Merbein Canner, Merbein Early, Merbein Midseason, Merbein Monarch resistant to *M. incognita*. Florida, Hawaii Cross, Gilestar, Hawaii 55 (Winstead and Riggs, 1963), Illinois T-19 (Hussein and Otiefa, 1956), VFN-368, Tuck Cross K, Kolea (Fassuliotis, 1976) cultivars of tomato were found resistant to *M. incognita*. Tomato cv. Leader was resistant to *M. javanica* (Lal and Hameed, 1969). Zaginailo (1970) screened some cultivars of tomato and found All Round and Eurocross resistant to *M. incognita*. Cultivars Atkinson and Manalucei were found resistant to *M. incognita*, *M. javanica* and *M. arenaria* by Singh and Chaudhury (1973). Sikora *et al*. (1973) screened certain cultivars of tomato for their resistance to *M. javanica* in India. Healani, Kalohi, Anahu, Hawaii 7526, Atkinson, Nematex, Y-207 and Y-240 showed no visible root-galling, whereas VFN-8 and VFN-368 cultivars were heavily galled.

Krnjaic *et al*. (1975) observed the response of 42 tomato cultivars grown in an hydroponic substrate heavily infested with *M. incognita*. Pinta was free from galls but the galling was high on Azes, Moira, B67, R12 and R52. Cultivars Rossol of tomato has been found resistant to *M. incognita* and *M. javanica*

(Fassuliotis, 1976; Netscher, 1976). Abu-Gharbieh (1978) screened over 100 tomato cultivars under glasshouse conditions for resistance to *M. incognita* and *M. javanica*. Fourteen cultivars exhibited a good level of resistance to one or both species. Varma (1978) studied nine cultivars of tomato and found certain degree of resistance in Pusa Ruby and Kech Ruth against *M. incognita*. Patel *et al*. (1976) found Nematex and S-120 varieties of tomato resistant against *M. incognita* and *M. javanica*. Stephan (1979) reported that out of 71 cultivars of tomato tested only 3 cultivars i.e. VFN-8, Rossol and Marmar were resistant against *M. javanica*. Kewalo, Healani and Druma were found resistant when 41 cultivars of tomato were screened against *M. incognita* by Sontirat (1981). Reyes and Villanueva (1981) reported that none of the 17 tomato varieties tested were resistant to *M. incognita*. Hemeng (1982) found only one line (AT-70/24) resistant in 17 cultivars of tomato to *M. incognita* and *M. javanica* . Yassin and Zeidan (1982) screened 6 varieties of tomato against *M. javanica*. Five of the six varieties i.e. Nemarid, Healani, Kalohi, Royal Chico and VFN-8 were found immune. Ibrahim (1982) tested 8 cultivars to populations of *M. incognita* (Race 1 and 3), *M. javanica* and *M. arenaria* race 1. The cultivars, AMEY-VFN, Monita, Patriot, VFN-Bush and VFN-8 were resistant. Cultivars, Better Boy Hybrid VFN, Nemason, Peirsol, and Peirsol Inra VFN were resistant out of 63 cultivars of tomato to *M. javanica* and *M. incognita* (Abu-Gharbieh, 1982).

Dabaj and Khan (1982) screened ten cultivars of tomato against M. javanica. Only one cultivar Tobol No.748 F_1 RS was found resistant. Lamberti et al. (1983) screened six tomato cultivars against local population of M. arenaria and M. javanica in Sri Lanka. They found one cultivar (Katugstota) susceptible and five cultivars (Brech, Bush, Piersol, Rossol and VFN) resistant. Jain et al. (1983) found tomato varieties, SL-12, Resistant Bangalore and SL-120 resistant to M. javanica. Narayana and Reddy (1983) found a tomato variety, NTDR-1 resistant to 10 isolates of M. incognita and susceptible to 4 isolates of M. javanica. Mahajan and Mangat (1984) screened 34 varieties of tomato against mixed population of M. incognita and M. javanica. Out of the varieties tested, Bigest, Bonus, Contess, Better, Boy, Monte Carlo, Beefmaster VFN-360, Peirnita, Motabo, Motella, Hessolini, Cl 3279, Cl 3104, and Cl B110 showed a varying degree of resistance. Rajkumar and Krishnappa (1984) found that cultivars like Pelican, Rossol, Ronita, VFN-8, Karnataka Hybrid and A-1-1-2 were resistant to Race 1, 2 and 3 of M. incognita. Raut (1986) while screening 10 tomato cultivars against M. incognita found only one cultivar (EC 118277) resistant to the species. Sasser et al. (1987) listed 25 accessions of tomato tested against the 4 major species and their races from The Asian Vegetable Research & Development Center (AVRDC). No resistance was found to M. hapla. Accessions, Roma - VC 8-1-2-1, Cl-106-5-1-0, Kewalo L 274, RV 12-L4109, RV 29-L 4126 and Atkinson-L 313 were resistant to all seven (M. incognita Races 1,2,3,4;

M. arenaria Races, 1,2; and M. javanica) of the remaining nematodes populations to which they were tested.

A number of cultivars of eggplant have been screened against root-knot nematodes for their resistance. Eggplant cv. Black Beauty was found moderately resistant to M. incognita (Sasser, 1954; Birat, 1966; Alam et al.,1974). Birat (1966) found Bhanta highly resistant and Muktakeshi and Round Red moderately resistant to M. javanica. Cultivars like Coolie and Mathis B were reported as resistant to M. javanica (Mathur et al., 1971), Meyer's Market resistant to M. incognita (Calinga and Palo, 1972), Giant of Banaras and Gola moderately resistant to M. incognita (Alam et al., 1974) and Vijaya resistant to M. incognita (Yadav et al., 1975). Varma (1977) found all the cultivars of eggplant, he tested susceptible to M. incognita. However, some cultivars like Mysore Green and Pusa Purple Long Black were tolerant. Valdez (1981) screened eggplant selections for resistance to M. incognita and M. javanica. None of 16 selections was rated as resistant to either test nematode. However, Dingran Long Purple, La Granja Long Purple and Florida Market showed moderate resistance to both nematode species. Similarly, Reyes and Villanueva (1981) screened 7 varieties of eggplant against M. incognita. Numaro Long, Dumaguete Long Purple and Annamalai Brinjai were rated resistant. Abu-Gharbieh (1982) screened 6 varieties of eggplant against M. incognita and M. javanica. None was rated resistant. Mysore Green, BR-112, Americaa Big Round, Arkasheel, R-34, Sonepat selection of eggplant were found moderately resistant to M.javanica by Jain et al. (1983). Reddy et al. (1986) evaluated 31 brinjal lines of diverse origins against M. incognita. Lines 'Maroo Marvel' and 'Brinjal BR 112' were resistant to the species.

In okra, Clemson Spineless has been found highly resistant to M. hapla and moderately resistant to M. arenaria (Sasser,1954). Long Green Smooth was found resistant to M. javanica (Birat,1966). Alam et al. (1974) found all the seven varieties of okra included in the test susceptible to M. incognita. Rao and Singh (1977) screened 34 varieties of okra. None of the varieties tested was rated resistant. Cultivars IC-9273, IC-18960 were found resistant against M. javanica by Jain et al. (1983). Thakar and Patel (1985) tested 7 varieties of okra to mixed population to M. incognita and M. javanica. All the tested varieties exhibited susceptible reaction.

In pepper, some cultivars have shown resistance to root-knot nematodes, Early California Wonder was reported moderately resistant to M. javanica (Hare, 1956); Oakview Wonder resistant to M. javanica and M. arenaria (Hare, 1956); Ruby King resistant to M. arenaria (Hare, 1957); 505 B Mexico and Santanka XS resistant to M. javanica, M. incognita and M. arenaria (Hare, 1957); World Beater resistant to M. incognita and highly resistant to M. javanica (Palo and Calinga, 1969; Sasser, 1954) and Bontoc Sweet Long and Dingras Rainy Season resistant to M. incognita (Palo and Calinga, 1969). California Wonder has been listed as resistant to M. javanica (Taylor and Sasser, 1978). All the 20 varieties of pepper tested against *M. incognita* by Reyes and Villanueva (1981) were rated resistant. Abu-Gharbieh (1982) screened 4 varieties of pepper and 6 of sweet pepper against *M. javanica* and *M. incognita*. All the varieties were rated resistant to the *M. javanica* and susceptible to *M. incognita* except California Yolo Wonder of sweet pepper which was resistant to both species. Chilli varieties Pusa Jawala, 579 and CAP 63 were reported resistant against *M. javanica* by Jain *et al*. (1983).

Cultivars of a number of cucurbits which are used as vegetables or ripe fruits have been screened to detect resistance against root-knot nematodes. Winstead and Sasser (1956) screened 50 cucumber varieties and reported all of them to be susceptible to *M. incognita*. Mathur *et al*. (1971) screened some varieties of muskmelon against *M. incognita* but did not record any variety resistant to the nematode. Abu-Gharbieh (1982) screened some cultivars of cucurbits against *M. javanica* and *M. incognita*. Of the 18 cucumber, 16 sweetmelon, 5 squash, 7 watermelon varieties tested, only 3 i.e. Top Kapi and Dima F_1 of squash were rated resistant to *M. javanica* and Crimson Sweet of watermelon to both. Reyes and Villanueva (1981) examined 5 varieties of cucumber for their resistance against *M. incognita*. Ashly and SMR-58 varieties were rated resistant. Jain *et al*. (1983) found muskmelon var. S-445 highly resistant to *M. javanica*. Ten varieties of watermelon and muskmelon were screened against *M. incognita* by Sharma *et al*. (1986) but none showed resistance. Recently, Darekar *et al*. (1988) screened 39 varieties of cucumber against Race 3 of *M. incognita*.

None of the varieties tested was found to be resistant except 'GY-5937-587' which was rated as moderately resistant.

Reyes and Villanueva (1981) screened 3 varieties of cabbage and 10 of lettuce against M. incognita. The cabbage varieties Leo 80 and K-K were rated resistant. All of the lettuce varieties used were found susceptible. Forty varieties of lettuce were observed against M. hapla, M. incognita and M. javanica but none was rated resistant (Nishizawa, 1981). Five accessions of Chinese cabbage from AVRDC were evaluated and no resistance was found to any of the four major species of Meloidogyne or to any of the their respective host races (Sasser et al., 1987).

The second stage juveniles of root-knot nematodes, Meloidogyne species constitute the infective stage. Root-knot nematode juveniles readily penetrate plant roots near the apical meristem within 24 hours after inoculation (Nemec, 1910; Siddiqui and Taylor, 1970). However, other regions of the root are not immune to attack (Christie, 1936). Meloidogyne second stage juveniles do not find roots by random movement, but are attracted to plants in response to stimuli emanating from roots (Green, 1971; Prot, 1980). Root exudates play an important role in both attracting and repelling root-knot nematodes. Sasser (1954) tested fifty plant species and varieties commonly used in crop rotation for susceptibility to root-knot nematodes and found that resistant plants were not penetrated as readily as susceptible plants. Griffin and Waite (1971) compared susceptible and resistant alfalfa cultivars in their attraction to M. hapla. They found little difference in attractiveness between individual susceptible and resistant plants; 90% and 70% of the nematode inoculum was attracted to the susceptible and resistant cultivars respectively. However, when both cultivars were inoculated simultaneously, 72% of the juveniles were attracted to the susceptible seedling and 28% migrated to the resistant seedling. Roy (1975) also reported that larvae of M. graminicola penetrated the rice roots of both susceptible and resistant cultivars with almost equal ease but further development of the nematode was reduced in the resistant cultivars, resulting in the production of fewer galls. Haynes and Jones (1976) reported that M.incognita was attracted significantly fewer to root of bitter cucumbers than to roots of non-bitter isogenic lines. Cucumber plants carrying a single dominant bitter gene (Bi) produce compounds that repel nematodes. Resistance to M. incognita in cowpea cultivars was investigated by Singh and Reddy (1985). The resistance was associated with reduced larval invasion, root galling, eggmass production and fecundity, delayed development of larvae to adult females.

From the foregoing it is evident that attempts have been made in past to evaluate the cultivars of vegetable crops for their resistance against root-knot nematodes especially M.incognita and *M. javanica* and some of cultivars have shown resistance too. But the inoculum levels and parameters or scales for measuring the resistance of the cultivars varied and consequently the degree of resistance assigned to cultivars were different in different studies. In view of the existence of four well-established races in *M. incognita*, the most dominant root-knot nematode species on worldwide basis and its quite frequent occurrence in mixed populations with *M. javanica*, the second commonest species of root-knot nematodes, re-evaluation of the cultivars of vegetables for their resistance against the races of *M. incognita* and *M. javanica* is greatly needed. At the same time in such re-evaluations standardized inoculum levels and parameters as suggested by Sasser *et al.* (1984) should be used. Therefore, in the present study, cultivars of some vegetables have been screened for their resistance against all the 4 races of *M. incognita* and against *M. javanica* in artificial inoculation, and standard host-suitability designations have been assigned following the suggestions of Sasser *et al.* (1984). Additionally, a comparative assessment of penetration and post-penetration development of *M. incognita* and *M. javanica* in the roots of resistant and susceptible cultivars has also been made.

MATERIALS AND METHODS

Response of vegetable cultivars to root-knot nematodes:

Cultivars under trial for introduction and commercial cultivars of tomato (*Lycopersicon esculentum* Mill.), eggplant (*Solanum melongena* L.), pepper (*Capsicum annuum* L.), okra (*Abelmoschus esculentus* (L.) Moen.), cucumber (*Cucumis sativus* L.), cauliflower (*Brassica oleracea* L.var. *botrytis*) and cabbage (*Brassica oleracea* L. var. *capitata*) were screened for their degree of resistance in glasshouse against *M. javanica* and Race 1, Race 2, Race 3 and Race 4 of *M. incognita*. Since these two species and all the 4 races of *M. incognita* were found most commonly distributed in the area surveyed during the present investigations, these nematodes were selected for screening the cultivars. Seedlings of tomato, eggplant, pepper, cauliflower and cabbage cultivars were raised in clay pots (30 cm) containing autoclaved soil and seedlings were later transplanted to individual pots filled with autoclaved soil. Seeds of okra and cucumber cultivars were, however, directly sown in pots. Plants in the 2 to 4 true leaf-stage were inoculated with 5000 freshly hatched second stage juveniles (J_2)/pot of *Meloidogyne* species. Three replicate pots were inoculated for each cultivar. Plants of a susceptible cultivar of tomato (Pusa Ruby) were also inoculated simultaneously to serve as control for determining the time of termination. After inoculation, plants were grown for 60 days at a temperature of 22-30 in glasshouse. After 60 days, plants were removed from pots and washed to discard adhered soil particles. Gall index (GI) and reproduction factor (R factor) were determined. Gall index was rated on 0-5 scale of Taylor and Sasser as mentioned under the survey (Section I).

To estimate the nematode reproduction , all the stages of nematodes and eggs were extracted from the roots separately. For their extraction chlorox method of Hussey and Barker (1973) were applied, except that the root system was finely chopped in a blender and a 1% NaOCl solution was used. Extracted nematodes and eggs were stained red with a few drops of acid fuchsin-acetic acid solution (3.5 g acid fuchsin, 250 ml acetic acid, 750 ml distilled water) and the suspension was boiled briefly (Byrd *et al.*, 1983). Soil population of nematodes was estimated by modified Cobb's sieving and decanting technique (Southey, 1970). The total population/plant (Pf) were estimated and average were determined. The reproduction factor was then calculated according to formula given by Oostenbrink (1966): $R = \frac{Pf}{Pi}$, where Pf represented the final population of nematodes and eggs recovered from soil and roots of the cultivars; Pi the initial population of 5,000 juveniles (J_2) with which the plants were inoculated.

Based on gall index and reproduction factor, the host susceptibility of cultivars (degree of resistance) were designated according to the modified scheme of Canto-Saenz (1983) as suggested by Sasser *et al.* (1984). The quantitative scheme for assignment of host suitability (resistance) designations is given below:

Plant damage (gall index)	Host efficiency (R factor)	Degree of resistance designation (DR)
≤ 2	≤ 1	Resistant
≤ 2	> 1	Tolerant
> 2	≤ 1	Hypersusceptible
> 2	> 1	Susceptible

According to Sasser et al. (1984) cultivars with $R > 1$ and $GI > 2$ are designated as susceptible. Such hosts are efficient for the pathogen and significant damage may occur. Cultivars with $R \leq 1$ and $GI > 2$ are designated as hypersusceptible. Such cultivars are poor hosts for the pathogen but significant damage may occur. Cultivars with $R > 1$ and $GI \leq 2$ are termed as tolerant where minimal damage is expected although the host is efficient for reproduction. Cultivars with $R \leq 1$ and $GI \leq 2$ are termed as resistant where the host is poor for nematode reproduction and galling, so minimal damage may occur.

All those plants with no nematode reproduction ($R=0$) and no root galling ($GI=0$) are categorized as immune and no plant damage is expected.

<u>Penetration and post-penetration development of root-knot nematodes in roots of susceptible and resistant cultivars</u>:

Penetration and post-penetration development of *M. javanica* and *M. incognita* Race 1, to which some cultivars of vegetables showed resistance, were studied in the following cultivars:

Vegetable	Susceptible cultivar	Resistant/Immune cultivar
Tomato	Pusa Ruby	EC173898 (72T6)
Pepper	Suryamukhi Green	Jwala
Cucumber	Point Sett	Improved Long Green
Cauliflower	Snow Ball No.16	74-6C
Cabbage	Pride of Asia	Suttons Eclipse Drumhead

Seedlings of above mentioned cultivars of the vegetables except cucumber were raised in clay pots filled with autoclaved soil. Two-week-old seedlings were transplanted to paper cups of 8 cm (one seedling/cup) filled with thoroughly washed sand and autoclaved soil (80% sand + 20% soil). For each vegetable 60 cups were used. The cups were divided in 2 sets of 30 cups. Seedlings of the resistant/immune cultivar were transplanted in the first set of 30 cups and of the susceptible cultivar in the second set of 30 cups. Each cup was inoculated with 1000 freshly hatched second stage juveniles (J_2) of *M. javanica*. Cucumber seeds were, however, directly sown in the cups and inoculated when seedlings were two-week-old. Cups were maintained at room temperature. Seedlings were uprooted at 6 time intervals i.e. 24, 48, 72h, 7, 15 and 30 days after inoculations. At each time interval, five seedlings from the resistant/immune cultivar set and five from the susceptible cultivar set were uprooted. Roots from each set were washed clean, stained with acid fuchsin and examined under the binocular microscope to determine the number of second, third/fourth (J_2, J_3/J_4) juvenile stages and pre-mature and adult females and total number of nematodes present in the root system.

For studying penetration and post-penetration development of *M. incognita* Race 1 in susceptible and resistant/immune cultivars of the vegetables, a similar experiment was done following the same methods as for *M. javanica* described above.

RESULTS

Response of vegetable cultivars to root-knot nematodes

Cultivars of seven vegetables viz., tomato, eggplant, pepper, okra, cucumber, cauliflower and cabbage were screened against Race 1, Race 2, Race 3 and Race 4 of *M. incognita* and *M. javanica*. Host suitability designations (degree of resistance) were assigned to each cultivar according to their performance against the nematodes following the Canto-Saenz scheme (1983) as suggested and modified by Sasser *et al*. (1984). Host suitability designations were based on gall index as indicator of plant damage and on the reproduction factor as an indicator of nematode reproduction (host efficiency) as given in Tables 2-8.

TOMATO :

Thirty six cultivars of tomato were screened against Race 1, Race 2, Race 3 and Race 4 of *M. incognita* and *M. javanica* and their degree of resistance was assigned according to the modified Canto-Saenz scheme (Sasser *et al*., 1984). On twenty one cultivars viz., Marglobe Supreme, Pusa Early Dwarf, Pusa Ruby, Pant-T3, Pant-T2, AC 238, Best of All, Panjab Choara, Bonney Best, Roma, Arka Vikas, Mikado, Suttons Roma, Pendulina, Potentate Best of All, Suttons Best of All, HS-101, Arka Saurabh, Local Cultivar (Bangalore), Rutgers and EC 173902 (Kagome) of tomato, all the four races of *M. incognita* as well as *M. javanica* reproduced efficiently

Table 1. Degree of resistance of cultivars of some vegetable crops tested against *Meloidogyne incognita* (Race 1,2,3,4) and *Meloidogyne javanica*.

Vegetable	*M. incognita*				*M. javanica*
	Race 1	Race 2	Race 3	Race 4	
Tomato (36)*	S=22; H=1; R=3 ; I=10	S=23; R=3; I=10	S=23; T=1; R=2 ; I=10	S=22; H=1; R=3 ; I=10	S=23; I=13
Eggplant (19)	S=All	S=All	S=All	S=All	S=All
Pepper (14)	S=12; R=2	S=12; H=1; R=1	S=12; R=1; I=1	S=13; R=1	S=2 ; H=2; R=5; I=5
Okra (10)	S=All	S=All	S=All	S=All	S=All
Cucumber (9)	S=All	S=All	S=8 ; H=1	S=8 ; H=1	S=8 ; R=1
Cauliflower (37)	S=20; H=13; R=3 ; I=1	S=20; H=11; R=5 ; I=1	S=24; H=10; R=2 ; I=1	S=23; H=8; T=2; R=3 ; I=1	S=17; H=17; R=1 ; I=2
Cabbage (23)	S=15; H=5; R=3	S=18; H=2; R=3	S=17; H=3; R=2 ; I=1	S=19; H=1; R=3	S=18; H=3; R=2

* Figure in parentheses in the column is the number of cultivars screened.

S = Susceptible; H= Hypersusceptible; T = Tolerant; R = Resistant; I = Immune.

Figures given against each degree of resistance in different columns indicate the number of cultivars assigned to that degree.

and caused sufficient root galls. All these cultivars were termed as efficient hosts for all the four races of M. incognita and M. javanica as reproduction factor (Rf) was invariably > 1. The range of reproduction factor was between 1.36 and 31.33. Gall index (GI) on these cultivars caused by the four races of M. incognita and M. javanica was > 2 (range 2.6-5.0). On the basis of these two considerations i.e. Rf and GI all these cultivars were designated susceptible (Table 2). On Pant-T1, GI caused by Race 1 of M. incognita was > 2 but Rf was < 1. Therefore, the cultivar was hypersusceptible to this race. To rest of the races of M. incognita as well as to M. javanica it was susceptible. On Money Maker GI of Race 4 of M. incognita was > 2 but Rf was 1. Consequently, this cultivars was also termed as hypersusceptible. To rest of the test nematodes, it was susceptible (Table 2).

Thirteen cultivars were found either tolerant/resistant/immune to one or other test nematode. Ten cultivars namely Pusa-120, Calmart VFN, Panjab 6. NR-7, EC173898 (72T6), EC173897 (Cal-Mart), EC173896 (Kewalo), CLN 363 BC_1F_2-167-1-0, CLN 363 BC_1F_2-190-1-0, CLN 363 BC_1F_2-344-0-0 and CLN 229 BC_1F_2-4-1-4-1-1-0 were found immune to all the test nematodes since the GI and Rf were nil. Pelican was rated as resistant to Race 1, Race 2, Race 4; tolerant to Race 3 and immune to M. javanica. Cultivars VFN-Bush and VFN-8 were resistant to all the four races of M. incognita but it was immune to M. javanica (Table 2).

Table 2. Host suitability (resistance) of 36 cultivars of tomato to races of *Meloidogyne incognita* and *Meloidogyne javanica*.

Cultivar	*M. incognita*																*M. javanica*			
	Race 1				Race 2				Race 3				Race 4							
	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR
Marglobe supreme	5.0	0.00	31.33	S	5.0	0.00	17.10	S	5.0	0.00	21.10	S	5.0	0.00	11.36	S	5.0	0.00	19.00	S
Pusa Early Dwarf	5.0	0.00	7.70	S	5.0	0.00	9.60	S	5.0	0.00	8.30	S	5.0	0.00	8.70	S	5.0	0.00	7.60	S
Pusa Ruby	5.0	0.00	9.02	S	5.0	0.00	11.40	S	5.0	0.00	15.70	S	5.0	0.00	15.80	S	5.0	0.00	4.60	S
Pusa-120	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
Pant-T_3	3.0	0.00	1.36	S	2.6	0.58	1.62	S	4.0	0.00	1.56	S	4.0	0.00	3.80	S	3.3	0.57	1.94	S
Pant-T_1	3.0	0.00	0.96	H	4.0	0.00	10.74	S	3.0	0.00	1.38	S	4.0	0.00	4.94	S	4.0	0.00	2.50	S
Pant T_2	3.3	0.57	2.06	S	5.0	0.00	7.48	S	3.0	0.00	1.84	S	4.6	0.58	9.20	S	5.0	0.00	14.30	S
AC 238	5.0	0.00	11.40	S	5.0	0.00	7.80	S	4.0	0.00	2.82	S	5.0	0.00	7.88	S	5.0	0.00	4.86	S
Best of All	5.0	0.00	13.01	S	5.0	0.00	9.60	S	5.0	0.00	7.78	S	5.0	0.00	7.48	S	5.0	0.00	4.04	S
Panjab Choara	5.0	0.00	7.66	S	5.0	0.00	8.00	S	5.0	0.00	8.53	S	4.3	1.15	5.00	S	5.0	0.00	2.98	S
Bonney Best	5.0	0.00	8.60	S	5.0	0.00	6.90	S	5.0	0.00	10.98	S	4.6	0.58	9.34	S	5.0	0.00	5.86	S
Roma	5.0	0.00	10.30	S	5.0	0.00	5.80	S	5.0	0.00	8.90	S	4.3	0.57	6.18	S	5.0	0.00	6.06	S
EC173898(72T6)	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
EC173897(Cal-Mart)	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
EC173896(Kewalo)	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
EC173902(Kagome)	3.3	0.57	1.36	S	4.0	0.00	2.76	S	3.0	0.00	2.24	S	4.0	0.00	2.90	S	4.0	0.00	2.16	S
CLN363BC_1F_2-167-1-0	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
CLN363BC_1F_2-190-1-0	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
CLN363BC_1 F_2-344-0-0	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
CLN229BC_1F_2-4-1-4-1-1-0	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.00	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
Arka Vikas	5.0	0.00	4.40	S	5.0	0.00	5.86	S	3.0	1.00	1.18	S	5.0	0.00	5.65	S	4.0	1.00	2.98	S

Contd..

Table 2 (continued)

Cultivar	*M. incognita*																*M. javanica*			
	Race 1				Race 2				Race 3				Race 4							
	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR
Mikado	5.0	0.00	10.40	S	5.0	0.00	3.86	S	5.0	0.00	9.20	S	5.0	0.00	11.40	S	5.0	0.00	4.20	S
Suttons Roma	5.0	0.00	4.20	S	5.0	0.00	6.10	S	4.0	0.00	5.30	S	4.0	0.00	6.20	S	4.0	0.00	3.90	S
Pendulina	4.0	1.00	4.20	S	5.0	0.00	6.30	S	3.6	0.58	7.00	S	4.0	0.00	6.00	S	4.3	0.57	4.54	S
Potentate Best of All	5.0	0.00	24.00	S	5.0	0.00	8.80	S	5.0	0.00	19.00	S	5.0	0.00	22.00	S	5.0	0.00	4.00	S
Suttons Best of All	5.0	0.00	14.00	S	4.6	0.58	4.73	S	5.0	0.00	13.00	S	5.0	0.00	11.00	S	5.0	0.00	4.18	S
Money Maker	3.0	1.00	1.38	S	3.0	0.00	1.50	S	3.0	0.00	1.44	S	3.0	0.00	1.00	H	3.0	0.00	2.20	S
HS-101	4.0	0.00	3.46	S	5.0	0.00	9.00	S	4.0	0.00	3.46	S	4.6	0.58	4.20	S	5.0	0.00	7.30	S
Calmart VFN	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
Pelican	0.6	0.94	0.20	R	1.0	0.70	0.00	R	0.6	1.74	1.20	T	1.3	1.22	0.00	R	0.0	0.00	0.00	I
VFN-Bush	1.0	1.40	0.40	R	0.6	0.98	0.00	R	1.3	1.22	0.00	R	1.0	0.70	0.00	R	0.0	0.00	0.00	I
VFN-8	0.6	0.40	0.00	R	0.6	0.40	0.00	R	1.0	0.70	0.00	R	0.6	0.98	0.00	R	0.0	0.00	0.00	I
Panjab 6.NR-7	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
Arka Saurabh	5.0	0.00	17.66	S	5.0	0.00	10.66	S	5.0	0.00	9.66	S	5.0	0.00	8.90	S	5.0	0.00	3.12	S
Local Cultivar (Bangalore)	5.0	0.00	9.10	S	5.0	0.00	6.86	S	5.0	0.00	10.10	S	4.0	1.00	5.70	S	5.0	0.00	5.93	S
Rutgers	5.0	0.00	25.00	S	5.0	0.00	27.50	S	5.0	0.00	16.20	S	5.0	0.00	19.00	S	5.0	0.00	24.00	S

GI = Gall index; SD = Standard deviation; R.factor = Reproduction factor; DR = Degree of resistance; S = Susceptible; H = Hypersusceptible;
T = Tolerant; R = Resistant; I = Immune.

When degree of resistance of cultivars was analysed for each test nematode, it was observed that to Race 1 of *M.incognita* 22 cultivars were susceptible, 1 hypersusceptible, 3 resistant and 10 immune; to Race 2, 23 were susceptible, 3 resistant and 10 immune; to Race 3, 23 were susceptible, 1 tolerant, 2 resistant and 10 immune; to Race 4, 22 were susceptible, 1 hypersusceptible, 3 resistant and 10 immune. Twenty three cultivars were susceptible and the rest 13 were immune to *M. javanica* (Tables 1 and 2).

EGGPLANT :

All the nineteen cultivars of eggplant screened against Race 1, Race 2, Race 3, Race 4 of *M. incognita* and *M. javanica* were found susceptible (Table 3). However, damage to plant based on gall index (GI) and host efficiency based on reproduction factor (Rf) varied. GI and Rf ranges were between 3.00 and 5.0; and 1.30 and 30.90 respectively for all races of *M. incognita* and *M. javanica*. Thus according to the modified Canto-Saenz scheme all cultivars fell in susceptible category. This implies that all the cultivars were efficient host to all the four races of *M. incognita* and *M. javanica* and may suffer significant damage if grown in fields infested with these nematode populations.

PEPPER :

Fourteen cultivars of pepper were tested against *M.javanica* and the races of *M. incognita*. Eleven cultivars namely Suryamukhi Green, Bull Nose, Hungarian Wax, Chinese Giant, Elephant Struck,

Table 3. Host suitability (resistance) of 19 cultivars of eggplant to races of *Meloidogyne incognita* and *Meloidogyne javanica*.

Cultivar	*M. incognita*																*M. javanica*			
	Race 1				Race 2				Race 3				Race 4							
	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR
Pusa Kranti	5.0	0.00	14.80	S	5.0	0.00	6.90	S	5.0	0.00	13.40	S	5.0	0.00	13.60	S	5.0	0.00	10.53	S
American Dil Bahar Bangi Gol	5.0	0.00	8.36	S	4.0	1.00	3.05	S	5.0	0.00	6.58	S	5.0	0.00	7.75	S	5.0	0.00	6.29	S
Special Baramasi Jhumkiya	5.0	0.00	9.65	S	5.0	0.00	10.50	S	4.0	0.00	3.58	S	3.6	0.58	3.13	S	4.0	1.00	3.88	S
Patal Lok Bagni Gol(Guchchhadar)	3.3	0.57	1.30	S	3.0	1.00	1.73	S	4.0	0.00	1.33	S	3.0	0.00	2.50	S	3.6	0.58	2.56	S
Pusa Purple Long	5.0	0.00	9.70	S	4.6	0.58	4.65	S	4.0	0.00	3.73	S	5.0	0.00	7.80	S	5.0	0.00	11.60	S
Brinjal Pant Rituraj	4.0	0.00	3.60	S	4.3	0.57	4.25	S	3.3	0.57	1.88	S	4.0	0.00	3.74	S	4.0	0.00	3.20	S
Pant Samrat	5.0	0.00	17.00	S	5.0	0.00	14.10	S	5.0	0.00	10.20	S	5.0	0.00	14.00	S	3.6	1.15	2.78	S
Muktakeshi	5.0	0.00	9.20	S	5.0	0.00	6.73	S	5.0	0.00	11.38	S	5.0	0.00	14.00	S	4.6	0.58	6.84	S
Manjari Gota	4.0	0.00	4.80	S	4.6	0.58	4.00	S	3.0	0.00	2.13	S	3.0	0.00	2.30	S	4.0	0.00	3.10	S
Long White	5.0	0.00	23.00	S	4.6	0.58	9.20	S	5.0	0.00	24.33	S	5.0	0.00	11.20	S	5.0	0.00	11.40	S
Round White	5.0	0.00	18.53	S	5.0	0.00	16.00	S	5.0	0.00	5.90	S	5.0	0.00	6.60	S	4.6	0.58	5.56	S
Baramashi	4.0	0.00	3.60	S	3.6	0.58	3.90	S	3.0	0.00	1.60	S	3.3	0.57	2.78	S	4.0	1.00	3.20	S
Long Purple	5.0	0.00	13.20	S	5.0	0.00	10.58	S	5.0	0.00	15.00	S	5.0	0.00	12.00	S	5.0	0.00	8.30	S
Black Beauty	5.0	0.00	16.30	S	5.0	0.00	6.91	S	4.0	0.00	4.70	S	5.0	0.00	7.20	S	5.0	0.00	9.00	S
Benares Giant	5.0	0.00	9.20	S	4.6	0.58	6.58	S	5.0	0.00	4.90	S	5.0	0.00	6.00	S	4.6	0.58	5.80	S
Pusa Purple Cluster	5.0	0.00	17.50	S	5.0	0.00	14.10	S	5.0	0.00	16.10	S	5.0	0.00	10.54	S	4.6	0.58	5.90	S
Nurki	5.0	0.00	14.96	S	5.0	0.00	10.38	S	5.0	0.00	15.80	S	5.0	0.00	11.40	S	5.0	0.00	7.00	S
Improved Muktakeshi	5.0	0.00	19.00	S	5.0	0.00	16.80	S	5.0	0.00	23.00	S	5.0	0.00	12.50	S	5.0	0.00	16.96	S
Gochha Baigan	5.0	0.00	23.94	S	5.0	0.00	13.20	S	5.0	0.00	30.90	S	5.0	0.00	8.54	S	5.0	0.00	10.70	S

GI = Gall index; SD = Standard deviation; R.factor = Reproduction factor; DR = Degree of resistance; S = Susceptible.

Chilli 6-4, Chilli N-P.46-A, Chilli G-3, Chilli P.C.I, Suryamukhi and California Wonder were found susceptible to all the four races of M. incognita. All the races of M. incognita produced good number of galls. The range of gall index (GI) was between 4.0 and 5.0. Thus GI on the cultivars was invaraibly > 2. Eggmasses were also produced in good number by the test pathogens. Reproduction factor (Rf) was invariably > 1. Based on GI and Rf all these cultivars were designated susceptible to all the races of M. incognita. The reactions of other 3 cultivars to the races of M. incognita were variable. Pusa Jwala was susceptible to Race 2 and Race 4 but resistant to Race 1 and Race 3. Cultivar Suryamukhi Black was susceptible to Race 1, Race 3, and Race 4 and hypersusceptible to Race 2. Cultivar Jwala was,however, either resistant/immune to all the four races. It was resistant to Race 1, Race 2, Race 4 and immune to Race 3 (Table 4).

Of fourteen cultivars tested against M. javanica, 2 cultivars, Suryamukhi Green and Chilli P.C.I. were susceptible; 2 cultivars, Elephant Struck and Chilli 6-4 were hypersusceptible, and 5 cultivars, Pusa Jwala, Suryamukhi Black, Hungarian Wax, Chilli G-3 and California Wonder were resistant according to GI and Rf. Five cultivars, Jwala, Bull Nose, Chinese Giant, Chilli N.P.46-A and Suryamukhi were found immune since no galling and eggmass production occurred on their roots (Table 4).

Table 4. Host suitability (resistance) of 14 cultivars of pepper to races of *Meloidogyne incognita* and *Meloidogyne javanica*.

Cultivar	*M. incognita*																*M. javanica*			
	Race 1				Race 2				Race 3				Race 4							
	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR
Pusa Jwala	1.6	0.58	0.62	R	4.6	0.58	5.58	S	2.0	0.00	0.50	R	4.6	0.58	3.50	S	1.0	0.70	0.03	R
Suryamukhi Black	5.0	0.00	4.06	S	4.0	0.00	5.60	H	5.0	0.00	4.48	S	4.0	0.00	2.54	S	0.6	0.98	0.05	R
Suryamukhi Green	5.0	0.00	4.52	S	4.0	0.00	3.60	S	5.0	0.00	5.24	S	4.0	0.00	3.02	S	3.3	0.57	2.03	S
Jwala	1.3	0.57	0.00	R	2.0	0.00	0.80	R	0.0	0.00	0.00	I	0.6	0.40	0.00	R	0.0	0.00	0.00	I
Bull Nose	5.0	0.00	7.24	S	5.0	0.00	7.38	S	4.0	0.00	3.88	S	4.0	0.00	4.00	S	0.0	0.00	0.00	I
Hungarian Wax	4.0	0.00	4.40	S	4.6	0.58	5.44	S	4.3	0.57	7.80	S	4.6	0.58	7.00	S	1.0	0.70	0.00	R
Chinese Giant	5.0	0.00	14.80	S	5.0	0.00	10.80	S	5.0	0.00	10.10	S	5.0	0.00	8.40	S	0.0	0.00	0.00	I
Elephant Struck	5.0	0.00	9.90	S	4.6	0.58	5.30	S	4.3	0.57	10.04	S	5.0	0.00	7.48	S	3.3	0.57	0.76	H
Chilli 6-4	4.0	0.00	3.02	S	4.0	0.00	1.96	S	4.0	0.00	3.40	S	4.0	0.00	3.78	S	3.0	1.00	0.76	H
Chilli N-P.46-A	5.0	0.00	8.10	S	4.3	0.57	4.26	S	5.0	0.00	8.04	S	5.0	0.00	8.70	S	0.0	0.00	0.00	I
Chilli G-3	5.0	0.00	9.10	S	5.0	0.00	8.20	S	5.0	0.00	12.84	S	5.0	0.00	14.60	S	2.0	1.00	0.00	R
Chilli P.C.I.	5.0	0.00	6.50	S	4.3	0.57	5.00	S	4.0	0.00	2.52	S	4.0	0.00	3.26	S	3.0	1.00	7.16	S
Suryamukhi	4.0	0.00	4.10	S	4.0	0.00	4.80	S	4.0	0.00	4.60	S	4.0	0.00	3.06	S	0.0	0.00	0.00	I
California Wonder	5.0	0.00	12.38	S	5.0	0.00	16.30	S	5.0	0.00	6.90	S	5.0	0.00	7.38	S	0.3	0.49	0.00	R

GI = Gall index; SD = Standard deviation; R.factor = Reproduction factor; DR = Degree of resistance
S = Susceptible H = Hypersusceptible ; R = Resistant; I = Immune.

When degree of resistance of cultivars was analysed for each test nematode, it was found that to Race 1 of *M. incognita* 12 cultivars were susceptible and 2 resistant; to Race 2, 12 were susceptible, 1 hypersusceptible and 1 resistant; to Race 3, 12 were susceptible, 1 resistant and 1 immune; to Race 4, 13 were susceptible and 1 resistant; and to *M. javanica*, 2 were susceptible, 2 hypersusceptible, 5 resistant and 5 immune (Tables 1 and 4).

OKRA :

All the ten cultivars of okra viz. Pusa Sawani, Long Green, Seven Dhari, Bhindi N5, Stuttons Makhamli, S-1-1, Suttons Improved Sawani, KS-312, KS-305 and Local Cultivar (Bangalore) screened against Race 1, Race 2, Race 3, Race 4 of *M. incognita* as well as *M. javanica* were found susceptible to all the test nematodes. Gall index (GI) range on the cultivars was between 3.3 and 5.0 and reproduction factor (Rf) range was between 1.32 and 22.00. Thus GI and Rf of all the test nematodes on each cultivar was > 2 and > 1 respectively. Consequently all the cultivars were designated as susceptible (Table 5).

CUCUMBER :

Of nine cultivars of cucumber tested against Race 1, Race 2, Race 3, Race 4 of *M. incognita* and against *M. javanica*, seven cultivars namely Point Sett, Poona White Wonder, Kakri Tar, All Season, Long Green, Poona Kheera and Local Cultivar (Bangalore) were found susceptible to all the test nematodes. On these

Table 5. Host suitability (resistance) of 10 cultivars of okra to races of *Meloidogyne incognita* and *Meloidogyne javanica*.

Cultivar	*M. incognita*																*M. javanica*			
	Race 1				Race 2				Race 3				Race 4							
	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR
Pusa Sawani	5.0	0.00	8.20	S	5.0	0.00	10.80	S	5.0	0.00	4.69	S	5.0	0.00	7.46	S	5.0	0.00	7.28	S
Long Green	5.0	0.00	11.33	S	4.3	0.57	13.78	S	5.0	0.00	13.20	S	5.0	0.00	14.00	S	4.3	0.57	7.46	S
Seven Dhari	5.0	0.00	22.00	S	5.0	0.00	10.88	S	5.0	0.00	12.24	S	5.0	0.00	13.20	S	5.0	0.00	9.86	S
Bhindi N5	4.0	0.00	4.77	S	5.0	0.00	13.40	S	4.6	0.58	8.42	S	3.6	0.58	2.00	S	4.0	0.00	6.13	S
Suttons Makhmali	5.0	0.00	4.60	S	5.0	0.00	6.72	S	5.0	0.00	4.53	S	5.0	0.00	5.20	S	5.0	0.00	8.80	S
S-1-1	4.0	0.00	2.66	S	4.0	0.00	4.66	S	5.0	0.00	6.66	S	4.0	0.00	4.74	S	5.0	0.00	13.86	S
Suttons Improved Sawani	5.0	0.00	13.60	S	5.0	0.00	5.84	S	5.0	0.00	12.26	S	5.0	0.00	9.86	S	5.0	0.00	10.80	S
KS-312	3.3	0.57	1.57	S	3.3	0.57	1.32	S	3.6	0.58	1.65	S	4.0	0.00	3.96	S	4.0	0.00	5.06	S
KS-305	5.0	0.00	6.40	S	5.0	0.00	11.20	S	5.0	0.00	9.20	S	4.6	0.58	8.66	S	5.0	0.00	10.00	S
Local Cultivar (Bangalore)	4.0	0.00	5.20	S	4.0	0.00	4.40	S	5.0	0.00	4.58	S	4.3	0.57	6.80	S	4.6	0.58	5.00	S

GI = Gall index; SD = Standard deviation; R.factor = Reproduction factor; DR = Degree of resistance; S = Susceptible cultivars gall index (GI) ranged between 3.0 and 5.0 and reproduction factor (Rf) range was between 1.25 and 10.43. Thus all the seven cultivars were termed as susceptible. Out of the two remaining cultivars one cultivar (Foot Kakri) was also susceptible to Race 1, Race 2 and Race 3 of M. incognita as well as to M. javanica but hypersusceptible to Race 4 of M. incognita. The other cultivar (Improved Long Green) was susceptible to Race 1, Race 2 and Race 4 and hypersusceptible to Race 3 of M. incognita. But it was resistant to M. javanica (Table 6).

Thus all the nine cultivars were susceptible to Race 1 and Race 2 of M. incognita, Eight cultivars were susceptible and one hypersusceptible to Race 3 and Race 4. To M. javanica eight cultivars were susceptible but one was resistant (Table 1 and 6).

CAULIFLOWER :

Thirty seven cultivars of cauliflower were screened for their resistance against all the four races of M. incognita and M. javanica. Eight cultivars, viz., Snow Ball No.16, Special Agahni Jaldbaz, Patna Early, 114-S, Early Kumari, Agani, Snow Ball Elite, and Suttons Dania were found susceptible as gall index (GI) was > 2 and reproduction factor (Rf) was > 1 on them. Cultivar Patna Mid Season was hypersusceptible to all the four races of M. incognita as well as to M. javanica because GI was > 2 and Rf $\leq$ 1. On cultivar Dania, no gall and eggmass production occurred. Therefore, it was designated immune to all the test nematodes (Table 7).

Table 6. Host suitability (*resistance*) of 9 cultivars of cucumber to races of *Meloidogyne incognita* and *Meloidogyne javanica*.

Cultivar	*M. incognita*																*M. javanica*			
	Race 1				Race 2				Race 3				Race 4							
	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR
Point Sett	5.0	0.00	8.50	S	5.0	0.00	7.70	S	5.0	0.00	7.26	S	5.0	0.00	6.32	S	3.6	0.58	3.94	S
Poona White Wonder	5.0	0.00	3.90	S	5.0	0.00	7.08	S	5.0	0.00	2.40	S	5.0	0.00	6.66	S	5.0	0.00	6.24	S
Foot Kakri	4.3	0.57	3.70	S	4.6	0.58	4.92	S	3.6	1.15	3.33	S	4.0	0.00	0.92	H	3.6	0.58	2.30	S
Kakri Tar	5.0	0.00	3.30	S	5.0	0.00	5.90	S	5.0	0.00	1.66	S	5.0	0.00	5.50	S	4.0	0.00	4.60	S
All Season	3.0	0.00	1.46	S	3.0	0.00	1.25	S	5.0	0.00	5.60	S	5.0	0.00	6.20	S	5.0	0.00	7.60	S
Long Green	5.0	0.00	3.70	S	5.0	0.00	10.43	S	5.0	0.00	3.60	S	3.3	0.57	1.80	S	3.6	0.58	3.73	S
Improved Long Green	4.0	0.00	2.60	S	5.0	0.00	4.50	S	3.0	0.00	0.76	H	2.6	1.15	2.34	S	1.3	1.22	0.29	R
Poona Kheera	5.0	0.00	9.16	S	5.0	0.00	7.43	S	4.3	0.57	3.80	S	4.0	0.00	3.18	S	4.3	0.57	4.93	S
Local Cultivar (Bangalore)	5.0	0.00	9.10	S	5.0	0.00	10.18	S	5.0	0.00	8.96	S	5.0	0.00	7.90	S	4.3	0.57	3.36	S

GI = Gall index; SD = Standard deviation; R.factor = Reproduction factor; DR = Degree of resistance.

S = Susceptible; H = Hypersusceptible; R = Resistant.

Remaining 27 cultivars showed variable reactions to the different test nematodes. Special Indian Snow Ball, Superial Maghi, Special Parijat Pusa, Silver King, Early of India, Kartiki Faizabadi Kalmi, Selected Special Maghi, Kumari Special Kalmi Hajipur, Katki, Early Snow Ball, 351-4 and Snow Ball were susceptible; 235-S, Massuria Snow Ball, Balwan Snow Ball, Super Snow Ball, Special Agahni Late, American White King (Vilayati), 236-S, Indian Snow Ball, Maghi, Late Snow Ball, Early Market and Suttons Pusi were hypersusceptible; and 74-6C, Pusa Snow Ball, Pusa Late were resistant to Race 1 of *M. incognita* (Table 7).

Cultivars 235-S, Super Snow Ball, Superial Maghi, Special Parijat Pusa, Kumari Special Kalmi Hajipur, Maghi, Late Snow Ball, Early Snow Ball, Early Market, 351-4, Snow Ball and Suttons Pusi were susceptible; 74-6C, Special Indian Snow Ball, Special Agahni Late, Silver King, American White King (Vilayati), Early of India, Kartiki Faizabadi Kalmi, Selected Special Maghi, 236-S and Pusa Late were hypersusceptible; and Pusa Snow Ball, Massuria Snow Ball, Balwan Snow Ball, Indian Snow Ball and Katki were resistant to Race 2 (Table 7).

To Race 3 of *M. incognita*, Pusa Snow Ball, Balwan Snow Ball, Special Indian Snow Ball, Super Snow Ball, Superial Maghi, Special Agahni Late, Special Parijat Pusa, Silver King, Kartiki Faizabadi Kalmi, Kumari Special Kalmi Hajipur, Maghi, Katki, Late Snow Ball, Early, Snow Ball, Early Market and Snow Ball were susceptible; 235-S, 74-6C, Massuria Snow Ball, American White King (Vilayati), Selected Special Maghi, 236-S, Indian Snow Ball, Pusa Late and 351-4 were hypersusceptible; and Early of India and Suttons Pusi were resistant (Table 7).

To Race 4 of M. incognita, 235-S, Massuria Snow Ball, Special Indian Snow Ball, Super Snow Ball, Superial Maghi, Special Agahni Late, Special Parijat Pusa, Silver King, Kartiki Faizabadi Kalmi, 236-S, Katki, Late Snow Ball, 351-4, Snow Ball and Suttons Pusi were susceptible; Balwan Snow Ball, Selected Special Maghi, Kumari Special Kalmi Hajipur, Indian Snow Ball, Maghi, Pusa Late and Early Snow Ball were hypersusceptible; 74-6C and Pusa Snow Ball were tolerant; and American White King (Vilayati), Early of India as well as Early Market were resistant (Table 7).

Cultivars 235-S, Super Snow Ball, Special Agahani Late, Silver King, Katki, Late Snow Ball, Early Snow Ball, 351-4 and Suttons Pusi were susceptible; Pusa Snow Ball, Massuria Snow Ball, Balwan Snow Ball, Special Indian Snow Ball, Special Parijat Pusa, American White King (Vilayati), Early of India, Kartiki Faizabadi Kalmi, Selected Maghi, Kumari Special Kalmi Hajipur, 236-S, Indian Snow Ball, Maghi, Pusa Late, Early Market and Snow Ball were hypersusceptible; 74-6C was resistant and Superial Maghi was immune to M. javanica (Table 7).

When degree of resistance of cultivars were analysed for each test nematode, it was observed that to Race 1 of M. incognita 20 cultivars were susceptible, 13 hypersusceptible, 3 resistant,

Table 7. Host suitability (resistance) of 37 cultivars of cauliflower to races of *Meloidogyne incognita* and *Meloidogyne javanica*.

Cultivar	*M. incognita*																*M. javanica*			
	Race 1				Race 2				Race 3				Race 4							
	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR
235-S	3.0	0.00	0.96	H	4.3	0.57	3.69	S	2.6	0.58	0.86	H	2.6	0.58	2.56	S	4.3	0.57	3.66	S
74-6C	1.6	0.58	0.17	R	3.0	0.00	0.25	H	3.0	0.00	0.53	H	2.0	0.00	1.28	T	2.0	0.00	0.51	R
Pusa Snow Ball	2.0	0.00	0.48	R	1.6	1.02	0.00	R	3.3	0.57	1.21	S	2.0	0.00	1.86	T	3.0	0.00	0.39	H
Massuria Snow Ball	2.3	0.57	0.90	H	2.0	0.00	0.00	R	2.0	0.00	0.57	H	3.0	0.00	1.16	S	2.3	1.15	0.54	H
Balwan Snow Ball	3.0	0.00	0.65	H	2.0	0.00	0.20	R	3.0	1.00	1.46	S	3.0	1.00	0.00	H	2.6	0.58	0.36	H
Special Indian Snow Ball	3.0	0.00	1.18	S	2.6	0.58	0.34	H	3.0	1.00	1.66	S	4.0	0.00	2.12	S	3.6	0.58	0.90	H
Snow Ball No.16	4.0	0.00	1.93	S	5.0	0.00	5.64	S	3.3	0.57	1.94	S	5.0	0.00	4.77	S	5.0	0.00	5.04	S
Super Snow Ball	3.3	0.57	1.00	H	3.3	0.75	1.26	S	5.0	0.00	4.69	S	4.3	0.57	3.93	S	3.3	0.57	1.06	S
Superial Maghi	5.0	0.00	5.46	S	5.0	0.00	6.00	S	4.0	0.00	3.06	S	4.0	0.00	2.95	S	0.0	0.00	0.00	I
Special Agahni Late	3.6	0.58	0.93	H	3.0	1.00	0.11	H	4.6	0.58	4.13	S	5.0	0.00	2.05	S	5.0	0.00	1.10	S
Special Parijat Pusa	4.3	0.57	1.40	S	4.0	0.00	1.57	S	5.0	0.00	5.33	S	5.0	0.00	4.00	S	4.6	0.58	0.97	H
Special Agahni Jaldbaz	5.0	0.00	4.74	S	5.0	0.00	3.20	S	4.3	0.57	3.12	S	4.6	0.58	3.13	S	3.6	0.58	1.12	S
Silver King	4.0	0.00	1.93	S	4.0	0.00	0.86	H	5.0	0.00	4.32	S	5.0	0.00	3.13	S	4.3	0.57	1.45	S
American White King (Vilayati)	3.0	0.00	0.82	H	3.0	0.00	0.42	H	3.0	0.00	0.66	H	2.0	0.00	0.13	R	2.3	0.57	0.46	H
Early of India	4.0	0.00	2.46	S	3.0	0.00	0.51	H	1.3	0.70	0.00	R	2.0	0.00	0.00	R	2.6	0.58	0.54	H
Kartiki Faizabadi Kalmi	4.3	0.57	2.44	S	3.6	0.58	0.90	H	4.0	0.00	1.88	S	5.0	0.00	4.16	S	3.3	0.57	0.98	H
Selected Special Maghi	4.6	0.58	5.74	S	3.3	0.57	1.00	H	4.0	0.00	0.53	H	4.0	0.00	0.86	H	4.3	0.57	0.44	H
Kumari Special Kalmi Hajipur	5.0	0.00	3.32	S	5.0	0.00	2.20	S	4.0	0.00	1.57	S	3.6	0.58	0.00	H	3.3	0.57	0.83	H

Contd...

Table 7 (*continued*)

Cultivar	*M. incognita*																*M. javanica*			
	Race 1				Race 2				Race 3				Race 4							
	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR
Patna Early	5.0	0.00	3.80	S	5.0	0.00	2.80	S	5.0	0.00	4.70	S	5.0	0.00	3.60	S	5.0	0.00	3.45	S
114-S	4.0	0.00	2.25	S	4.3	0.57	1.80	S	5.0	0.00	7.73	S	5.0	0.00	7.00	S	4.3	0.57	1.52	S
236-S	5.0	0.00	0.30	H	3.3	0.57	0.90	H	4.0	0.00	0.14	H	5.0	0.00	4.26	S	3.6	0.58	0.72	H
Indian Snow Ball	4.0	0.00	0.28	H	0.6	0.98	0.00	R	3.0	0.00	0.00	H	4.0	0.00	0.50	H	3.3	0.57	0.80	H
Early Kumari	5.0	0.00	6.17	S	4.6	0.58	2.30	S	4.3	0.57	2.46	S	4.6	0.58	5.28	S	4.6	0.58	2.26	S
Maghi	3.0	0.00	0.28	H	4.3	0.57	2.53	S	4.0	0.00	1.90	S	3.6	0.58	1.00	H	3.3	0.57	0.80	H
Agani	5.0	0.00	1.80	S	4.6	0.58	1.65	S	4.6	0.58	2.86	S	5.0	0.00	6.40	S	4.6	0.58	2.05	S
Katki	4.0	1.00	1.65	S	0.6	0.40	0.00	R	4.3	0.57	3.60	S	4.6	0.58	4.16	S	4.3	0.57	1.90	S
Snow Ball Elite	5.0	0.00	3.84	S	2.0	0.00	2.00	S	5.0	0.00	7.00	S	4.6	0.58	4.61	S	3.3	0.57	1.50	S
Dania	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
Pusa Late	2.0	0.00	0.33	R	3.6	0.58	0.85	H	3.3	0.58	0.60	H	4.0	0.00	1.00	H	2.6	0.58	0.31	H
Patna Mid Season	3.0	0.00	0.24	H	3.0	0.00	0.94	H	3.0	0.00	0.74	H	2.3	0.57	0.80	H	3.0	0.00	0.68	H
Late Snow Ball	3.0	0.00	0.84	H	3.0	0.00	1.05	S	4.0	0.00	1.64	S	2.6	0.58	1.20	S	3.3	0.57	1.85	S
Early Snow Ball	4.6	0.58	5.45	S	4.6	0.58	2.15	S	3.6	0.58	1.14	S	3.3	0.57	0.74	H	4.0	1.00	1.25	S
Early Market	3.0	0.00	0.20	H	4.3	0.57	2.76	S	4.0	0.00	2.53	S	2.0	0.00	0.48	R	3.6	0.58	0.91	H
351-4	4.6	0.58	3.00	S	4.0	0.00	1.79	S	4.0	0.00	0.80	H	5.0	0.00	4.61	S	4.0	1.00	1.94	S
Snow Ball	5.0	0.00	2.20	S	3.3	1.52	1.20	S	5.0	0.00	2.40	S	4.6	0.58	4.33	S	2.6	1.72	0.75	H
Suttons Pusi	2.6	0.58	0.14	H	3.3	0.57	2.00	S	2.0	0.00	0.00	R	3.6	1.52	2.20	S	4.6	0.58	1.62	S
Suttons Dania	4.6	0.58	2.60	S	4.3	0.57	2.58	S	4.0	0.00	2.17	S	4.3	0.57	2.93	S	3.3	1.52	1.25	S

GI = Gall index; SD = Standard deviation; R.factor = *Reproduction factor*; DR = *Degree of resistance*; S = *Susceptible*; H = *Hypersusceptible*; T = Tolerant; R = Resistant; I = Immune.

and 1 immune; to Race 2, 20 were susceptible, 11 hypersusceptible, 5 resistant, and 1 immune; to Race 3, 24 were susceptible, 10 hypersusceptible, 2 resistant and 1 immune; to Race 4, 23 were susceptible, 8 hypersusceptible, 2 tolerant, 3 resistant and 1 immune; and to *M. javanica* 17 were susceptible, 17 hypersusceptible, 1 resistant and 2 immune (Tables 1 and 7).

CABBAGE :

Twenty three cultivars of cabbage were screened against Race 1, Race 2, Race 3, Race 4 of *M. incognita* and against *M. javanica*. Only 10 cultivars viz., Special Pride (60 Dinwali), Jaldbaz, Glory, Earliest Large Solid Drumhead, Pride of Asia, Chinese Wong Bok, Large Blood Red, September, Express Pointed (EC 168072) and Double Express were susceptible to all the test nematodes, as on all these cultivars GI was > 2 and Rf was > 1 (Table 8).

Remaining 13 cultivars showed variable reactions to the different test nematodes. Cultivars Golden Acre, Early, Copenhagen Market, Suttons Express and Suttons Pride of India were susceptible; Early Express (60 Dinwali), Cabbage September, Pride of India, Large Solid Late Drumhead and Glory of Enkhuizen were hypersusceptible; and American Special Ball Head, Red Drumhead and Suttons Eclipse Drumhead were resistant to Race 1 of *M. incognita*. Golden Acre, Early Express (60 Dinwali), Early, Cabbage September, Pride of India, Copenhagen Market, Large Solid Late Drumhead, Suttons Pride of India were susceptible; Red Drumhead and Suttons Express were hypersusceptible; and American Special Ball Head, Glory of Enkhuizen and Suttons Eclipse Drumhead were resistant to Race 2 of *M. incognita*. Cultivars Early Express (60 Dinwali), Early, Cabbage September, Pride of India, Copenhagen Market, Large Solid Late Drumhead and Sutton Express were susceptible; Golden Acre, Suttons Eclipse Drumhead and Suttons Pride of India were hypersusceptible; Red Drumhead and Glory of Enkhuizen were resistant; and American Special Ball Head was immune to Race 3 of *M. incognita*. Cultivars Golden Acre, Early Express (60 Dinwali), Early, Cabbage September, Pride of India, Red Drumhead, Large Solid Late Drumhead, Suttons Express and Suttons Pride of India were susceptible; Copenhagen Market was hypersusceptible; and American Special Ball Head, Glory of Enkhuizen and Suttons Eclipse Drumhead were resistant to Race 4 of *M. incognita* (Table 8).

To *M. javanica*, Golden Acre, Early Express (60 Dinwali), Cabbage September, Pride of India, Red Drumhead, Copenhagen Market, Large Solid Late Drumhead and Suttons Express were susceptible; Early, Glory of Enkhuizen and Suttons Pride of India were hypersusceptible; and American Special Ball Head and Suttons Eclipse Drumhead were resistant (Table 8).

When performance of cultivars were analysed for each test nematode, it was observed that to Race 1 of *M. incognita*, 15 cultivars were susceptible, 5 hypersusceptible and 3 resistant; to Race 2 18 were susceptible, 2 hypersusceptible and 3 resistant;

Table 8. Host suitability (resistance) of 23 cultivars of cabbage to races of <u>Meloidogyne incognita</u> and <u>Meloidogyne javanica</u>.

Cultivar	*M. incognita*																*M. javanica*			
	Race 1				Race 2				Race 3				Race 4							
	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR
Golden Acre	4.0	0.00	3.21	S	4.0	0.00	2.49	S	3.3	0.57	1.00	H	5.0	0.00	5.08	S	3.6	1.52	2.33	S
Early Express (60 Dinwali)	4.0	0.00	0.74	H	4.0	0.00	1.46	S	4.0	0.00	2.16	S	5.0	0.00	2.80	S	4.0	1.00	3.36	S
Special Pride (60 Dinwali)	4.6	0.58	6.05	S	4.0	0.00	5.21	S	5.0	0.00	5.93	S	5.0	0.00	2.53	S	5.0	0.00	5.93	S
American Special Ballhead	2.0	0.00	0.00	R	0.6	0.98	0.00	R	0.0	0.00	0.00	I	0.6	0.98	0.00	R	0.6	0.98	0.00	R
Jaldbaz	5.0	0.00	5.53	S	5.0	0.00	5.77	S	4.0	0.00	2.89	S	5.0	0.00	4.93	S	4.0	0.00	2.36	S
Early	5.0	0.00	5.53	S	4.6	0.58	2.76	S	4.6	0.58	4.82	S	4.6	0.58	1.98	S	4.0	0.00	0.66	H
Glory	5.0	0.00	5.20	S	3.0	0.00	1.12	S	4.0	0.00	1.88	S	4.0	0.00	1.69	S	4.0	0.00	2.14	S
Cabbage September	3.0	0.00	0.96	H	4.0	0.00	2.01	S	4.0	0.00	2.60	S	3.0	0.00	1.04	S	3.6	0.58	1.46	S
Pride of India	3.0	0.00	0.86	H	4.0	0.00	2.78	S	4.0	0.00	2.10	S	4.0	0.00	2.29	S	4.0	0.00	1.53	S
Red Drumhead	2.0	0.00	0.00	R	2.3	1.52	0.42	H	2.0	1.41	0.42	R	4.3	0.57	2.28	S	4.0	0.00	2.53	S
Copenhagen Market	5.0	0.00	6.38	S	4.0	0.00	2.02	S	4.0	0.00	2.52	S	3.0	0.00	0.97	H	5.0	0.00	5.02	S
Earliest Large Solid Drumhead	4.0	0.00	2.25	S	4.0	0.00	3.66	S	4.0	0.00	2.58	S	4.0	0.00	3.29	S	4.3	0.57	1.82	S
Pride of Asia	5.0	0.00	5.69	S	4.3	0.57	1.13	S	4.0	0.00	2.04	S	5.0	0.00	4.65	S	5.0	0.00	6.93	S
Large Solid Late Drumhead	3.0	0.00	0.00	H	3.3	1.52	2.00	S	4.0	0.00	3.12	S	4.0	0.00	3.45	S	4.6	0.58	2.22	S

Contd....

Table 8 (continued)

Cultivar	*M. incognita*																*M. arenaria*			
	Race 1				Race 2				Race 3				Race 4							
	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR	Mean GI	SD	R.factor	DR
Glory of Enkhuizen	2.3	0.57	0.32	H	2.0	1.00	0.16	R	2.0	1.00	0.00	R	2.0	1.00	0.33	R	3.0	0.00	0.80	H
Suttons Eclipse Drumhead	2.0	1.00	0.18	R	1.6	0.58	0.22	R	3.0	0.00	0.90	H	2.0	0.00	0.20	R	2.0	0.00	0.32	R
Suttons Express	5.0	0.00	6.02	S	2.6	0.58	0.50	H	4.0	0.00	2.52	S	4.0	0.00	2.74	S	5.0	0.00	3.36	S
Suttons Pride of India	5.0	0.00	3.78	S	4.6	0.58	2.16	S	3.0	0.00	0.69	H	4.0	1.00	1.20	S	4.6	0.58	1.00	H
Chinese Wong Bok	5.0	0.00	5.92	S	5.0	0.00	8.17	S	5.0	0.00	4.84	S	5.0	0.00	5.76	S	4.0	1.00	1.97	S
Large Blood Red	5.0	0.00	5.16	S	4.0	0.00	3.04	S	5.0	0.00	5.62	S	5.0	0.00	1.96	S	5.0	0.00	4.40	S
September	4.0	0.00	1.66	S	4.0	0.00	1.33	S	5.0	0.00	2.30	S	4.0	0.00	3.05	S	4.0	0.00	2.48	S
Express Pointed (EC168072)	5.0	0.00	7.20	S	4.0	0.00	3.02	S	5.0	0.00	5.72	S	5.0	0.00	6.40	S	5.0	0.00	5.01	S
Double Express	5.0	0.00	4.13	S	5.0	0.00	4.41	S	5.0	0.00	5.36	S	5.0	0.00	6.86	S	5.0	0.00	6.14	S

GI = Gall index; SD = Standard deviation; R.factor = Reproduction factor; DR = Degree of resistance; S = Susceptible; H = Hypersusceptible;

R = Resistant; I = Immune.

to Race 3 17 were susceptible, 3 hypersusceptible, 2 resistant and 1 immune; to Race 4, 19 were susceptible, 1 hypersusceptible and 3 resistant; and to *M. javanica* 18 were susceptible, 3 hypersusceptible and 2 resistant (Tables 1 and 8).

Penetration and post-penetration development of root-knot nematodes in roots of susceptible and resistant cultivars

Juveniles (J_2) penetration of *M. javanica* and *M. incognita* Race 1 in roots and their post-penetration development were observed in some resistant/immune and susceptible cultivars of tomato, pepper, cucumber, cauliflower and cabbage. A perusal of results showed that juvenile penetration of both the nematodes was much greater in susceptible cultivars of all the vegetables used in the study than resistant cultivars. This difference was noticed at all the time intervals of observation. The number of juveniles that penetrated the roots at a given time interval, however, varied with the vegetable. The details of results are presented for each vegetable crop below.

TOMATO :

In roots of the susceptible cultivar, Pusa Ruby 231 second stage juveniles (J_2) of *M. javanica* were found after 24h. After 72h, 305 J_2 had penetrated the roots. After a week, total penetration was 441; out of which 316 were in J_2 stage and 125 in J_3/J_4 stages and no adult female was found. When observed after

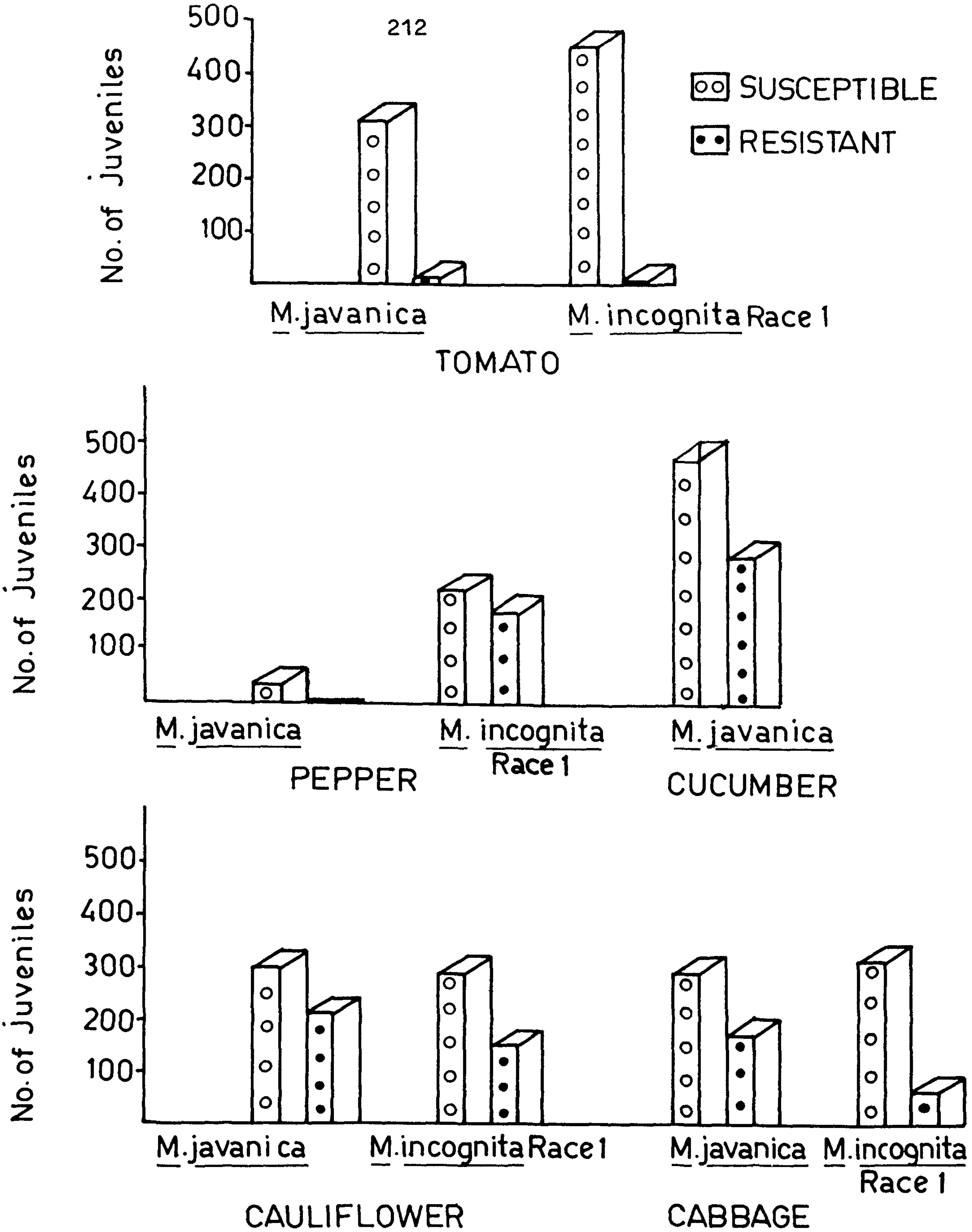


Fig.1: TOTAL JUVENILE PENETRATION OF ROOT-KNOT NEMATODES IN ROOTS OF SUSCEPTIBLE AND RESISTANT CULTIVARS OF VEGETABLES AFTER 30 DAYS .

15 days, 386 individuals of the nematode were found in different stages of development. After 30 days, total penetration was 312; of which 205 had developed into females and 85 were in J_3/J_4 stage and 22 in J_2 stage. On the other hand, in the cultivar EC 173898 (72 T6) which was designated as immune to M. *javanica* in screening, no penetration was observed upto 15 days. After 30 days, 10 J_2 were found in the root. The difference in penetration of the nematode juveniles between susceptible and immune cultivars was highly significant (Table 9; Fig.1).

A similar trend in juvenile penetration of M. *incognita* Race 1 in the susceptible and the immune cultivars of tomato was also observed (Table 9). The penetration of juveniles was significantly greater in susceptible cultivar. In the immune cultivar, after 30 days of inoculation, only 5 nematodes, all in J_2 stage were found in contrast to 454 in the susceptible cultivar; of which 243 had matured as females (Table 9; Fig.1).

PEPPER :

When a susceptible cultivar of pepper, Suryamukhi Green was inoculated with M. *javanica*, very few juveniles penetrated the roots. After 30 days, total penetration was 38 of which 5 had developed into females. In Jwala, a cultivar immune to M. *javanica*, no penetration was observed at all the time intervals. The difference in penetration of juveniles between susceptible and immune cultivars was highly significant (Table 10; Fig.1).

Table 9. Penetration and post-penetration development of Meloidogyne javanica and Meloidogyne incognita Race 1 in susceptible and immune cultivars of tomato.

Time period	Susceptible[a]			Total	Immune[b]			Total
	J_2	J_3/J_4	♀		J_2	J_3/J_4	♀	
				M. javanica				
24h	231	–	–	231	–	–	–	–
48h	280	–	–	280	–	–	–	–
72h	305	–	–	305	–	–	–	–
1 week	316	125	–	441	–	–	–	–
15 days	40	210	136	386	–	–	–	–
30 days	22	85	205	312*	10	–	–	10*
				M. incognita Race 1				
24h	235	–	–	235	–	–	–	–
48h	288	–	–	288	–	–	–	–
72h	317	–	–	317	–	–	–	–
1 week	337	119	–	456	–	–	–	–
15 days	35	246	155	436	–	–	–	–
30 days	–	211	243	454*	5	–	–	5*

[a]cv. Pusa Ruby = Susceptible to both

[b]cv. EC173898 (72T6) = Immune to both

* 't' significant both at P=0.05 and P=0.01

– = Nil

J_2 = Second stage juvenile; J_3/J_4 = Third/Fourth stage juvenile;
♀ = Mature female

Each value is mean of five replicates.

In the susceptible cultivar (Suryamukhi Green), ingress of juveniles of M. incognita Race 1 started from the very begining. After 24h, 140 juveniles were observed in the roots. Ingress of juveniles increased gradually and after one week 282 juveniles (J_2) were found in the roots. After 15 days, total penetration was 267. Total penetration was 222 after 30 days; of which 72 were females and 110 in J_3/J_4 stage and 40 in J_2 stage (Table 10; Fig.1).

In Jwala a cultivar resistant to M. incognita Race 1, very little penetration was observed after 24h. Only 91 juveniles penetrated the roots upto 1 week, all being in J_2 stage. After 15 days total penetration was 124; of which 14 were in J_3/J_4 stage. After 30 days of inoculation, 179 nematodes observed 5 were mature females, 19 in J_3/J_4 stage and 155 in J_2 stage. The difference in juvenile penetration of M. incognita Race 1 between susceptible and resistant cultivars was also highly significant (Table 10; Fig.1).

CUCUMBER :

A significant difference in juvenile penetration of M. javanica in roots of susceptible and resistant cultivars was found. In the roots of susceptible cultivar Point Sett, 182 juvenile penetrated after 24h. Penetration gradually increased upto a week. Out of 491 individuals that penetrated after a week, 301 had developed into J_3/J_4 stage. After 15 days, out of 462 individuals found penetrated in the root, 216 were

Table 10. Penetration and post-penetration development of *Meloidogyne javanica* and *M. incognita* Race 1 in susceptible and resistant/immune cultivars of pepper.

Time period	Susceptible[a]			Total	Resistant[b]			Total
	J_2	J_3/J_4	♀		J_2	J_3/J_4	♀	
				M. javanica				
24h	-	-	-	-	-	-	-	-
48h	1	-	-	1	-	-	-	-
72h	10	-	-	10	-	-	-	-
1 week	11	-	-	11	-	-	-	-
15 days	20	-	-	20	-	-	-	-
30 days	31	2	5	38*	-	-	-	-
				M. incognita Race 1				
24h	140	-	-	140	5	-	-	5
48h	184	-	-	184	43	-	-	43
72h	197	-	-	197	80	-	-	80
1 week	282	-	-	282	91	-	-	91
15 days	177	80	10	267	110	14	-	124
30 days	40	110	72	222*	155	19	5	179*

[a] cv. Suryamukhi Green = Susceptible to both

[b] cv. Jwala = Immune to *M. javanica* and Resistant to *M. incognita* Race 1

*'t' significant both at P=0.05 and P=0.01

\- = Nil

J_2 = Second stage juvenile; J_3/J_4 = Third/Fourth stage juvenile;

♀ = Mature female

Each value is mean of five replicates.

females, 204 in J_3/J_4 stage and only 42 in J_2 stage. After 30 days out of 464 individuals, 290 were females and 174 in J_3/J_4 stage (Table 11; Fig.1).

Ingress of juveniles of M. javanica in the roots of resistant cultivar Improved Long green, was comparatively higher than resistant/immune cultivars of other vegetables. But the total number of penetrated juveniles was still less than in susceptible cultivar of cucumber at all time intervals (Table 11). A difference in the rate of development was also observed. Some juveniles were found in J_2 stage after 30 days in resistant cultivar whereas in susceptible cultivar no juveniles was in J_2 stage. The difference in penetration of juveniles between susceptible and resistant cultivars was significant both at P=0.01 and P=0.05 (Table 11; Fig.1).

Since no cultivar of cucumber was found resistant to M. incognita races, root penetration study for M. incognita Race 1 was not undertaken.

CAULIFLOWER :

When a susceptible cultivar of cauliflower, Snow Ball No.16 was inoculated with M. javanica juveniles, a gradual increase in penetration occurred upto a week. Females were observed after 15 days. Total penetration was 299 after 30 days; of which 112 were already transformed into mature females; 105 were in J_3/J_4 stage and 82 in J_2 stage. In the resistant cultivar 74-6C, penetration was very slow. After a week, only 196

Table 11. Penetration and post-penetration development of <u>Meloidogyne javanica</u> in susceptible and resistant cultivars of cucumber.

Time period	Susceptible[a] J_2	J_3/J_4	♀	Total	Resistant[b] J_2	J_3/J_4	♀	Total
24h	182	-	-	182	172	-	-	172
48h	295	-	-	295	190	-	-	190
72h	325	-	-	325	227	-	-	227
1 week	190	301	-	491	245	83	-	328
15 days	42	204	216	462	175	196	15	386
30 days	-	174	290	464*	27	94	106	227*

[a] cv. Point Sett = Susceptible

[b] cv. Improved Long Green = Resistant

*'t' significant both at P=0.05 and P=0.01

- = Nil

J_2 = Second stage juvenile; J_3/J_4 = Third/Fourth stage juvenile;

♀ = Mature female

Each value is mean of five replicates.

individuals had penetrated the roots, and all were in J_2 stage. Total number of nematode individuals counted after 15 and 30 days were also comparatively less in resistant cultivar than in susceptible cultivar. None of the juvenile developed into female. A significant difference in juvenile penetration between susceptible and resistant cultivars was found (Table 12; Fig.1).

A similar trend and significant difference in juvenile penetration of M. incognita Race 1 between susceptible and resistant cultivar of cauliflower were also observed (Table 12; Fig.1).

CABBAGE :

Total penetration of juveniles of M. javanica in the roots of a susceptible cultivar of cabbage, Pride of Asia was greater than in the roots of a resistant cultivar, Suttons Eclipse Drumhead at all the time intervals (Table 13). In the susceptible cultivar after a week, out of 273 penetrated juveniles, 72 had developed into J_3/J_4 stage, and after 15 days out of 286, 40 had developed into females, 80 in J_3/J_4 stage and remaining were in J_2 stage. After 30 days, out of 287, 107 had developed into females and remaining were in J_3/J_4 and J_2 stages. In the resistant cultivar on the other hand upto 15 days all the penetrated juveniles were at J_2 stage. However, after 30 days only 15 juveniles developed into J_3/J_4 stage and total penetration was 170. The difference in penetration of juveniles after 30 days

Table 12. Penetration and post-penetration development of *Meloidogyne javanica* and *Meloidogyne incognita* Race 1 in susceptible and resistant cultivars of cauliflower.

Time period	Susceptible[a]			Total	Resistant[b]			Total
	J_2	J_3/J_4	♀		J_2	J_3/J_4	♀	
				M. javanica				
24h	187	-	-	187	156	-	-	156
48h	226	-	-	226	180	-	-	180
72h	252	-	-	252	184	-	-	184
1 week	270	80	-	350	196	-	-	196
15 days	180	115	30	325	187	16	-	203
30 days	82	105	112	299*	175	32	-	207*
				M. incognita Race 1				
24h	161	-	-	161	138	-	-	138
48h	218	-	-	218	158	-	-	158
72h	230	-	-	230	185	-	-	185
1 week	245	46	-	291	195	-	-	195
15 days	146	117	43	306	152	9	-	161
30 days	76	114	96	286*	134	14	-	148*

[a] cv. Snow Ball No.16 = Susceptible to both

[b] cv. 74-6C = Resistant to both

*'t' significant both at P=0.05 and P=0.01

- = Nil

J_2 = Second stage juvenile; J_3/J_4 = Third/Fourth stage juvenile;

♀ = Mature female

Each value is mean of five replicates.

Table 13. Penetration and post-penetration development of Meloidogyne javanica and Meloidogyne incognita Race 1 in susceptible and resistant cultivars of cabbage.

Time period	Susceptible[a]			Total	Resistant[b]			Total
	J_2	J_3/J_4	♀		J_2	J_3/J_4	♀	
				M. javanica				
24h	195	-	-	195	132	-	-	132
48h	244	-	-	244	172	-	-	172
72h	270	-	-	270	180	-	-	180
1 week	201	72	-	273	175	-	-	175
15 days	166	80	40	286	165	-	-	165
30 days	105	75	107	287*	155	15	-	170*
				M. incognita Race 1				
24h	182	-	-	182	122	-	-	122
48h	222	-	-	222	164	-	-	164
72h	245	-	-	245	156	-	-	156
1 week	262	40	-	302	146	-	-	146
15 days	202	95	23	320	145	-	-	145
30 days	177	45	85	307*	45	11	-	56*

[a] cv. Pride of Asia = Susceptible to both

[b] cv. Suttons Eclipse Drumhead = Resistant to both

* 't' significant both at P=0.05 and P=0.01

\- = Nil

J_2 = Second stage juvenile; J_3/J_4 = Third/Fourth stage juvenile;

♀ = Mature female

Each value is mean of five replicates.

between susceptible and resistant cultivars was significant (Table 13; Fig.1).

A similar trend in penetration of juveniles of *M. incognita* Race 1 in the susceptible and the resistant cultivars of cabbage was also observed (Table 13). In the resistant cultivar, only 56 individuals were found after 30 days; of which 11 were in J_3/J_4 stage in contrast to 307 individuals of different stages in the susceptible cultivar. Even after 30 days, none developed into females. The difference in penetration of juveniles after 30 days between susceptible and resistant cultivars was significant (Table 13; Fig.1).

DISCUSSION

Plant resistance is an effective and economical means of reducing losses from root-knot nematodes. The importance of managing root-knot nematodes through resistance of plants have gained further significance in the last few years because of certain health hazards involved in use of nematicides (Fassuliotis, 1979). The recognition of races within *M.incognita* and *M. arenaria* has opened new areas of research. Fassuliotis (1985) rightly suggested that many, if not all of the cultivars already reported to have some resistance will have to re-evaluated because previously reported resistance may be race specific. He asserted that from the data that has been collected by IMP, a crop having resistance to all the races of *M. incognita* and *M. javanica* would be resistant to 82% of the major *Meloidogyne* populations around the world. Tomato carrying resistance to *M. incognita*, *M. javanica* and *M. arenaria* would be resistant to 90% of the root-knot populations. In the present investigations, cultivars of tomato, eggplant, pepper, okra, cucumber, cauliflower and cabbage were screened against all the four races of *M. incognita* and *M. javanica* in order to evaluate their degree of resistance, so that cultivars showing resistance can be used by growers for root-knot free crops. The response of the cultivars to Race 1, Race 2, Race 3, Race 4 of *M. incognita* and *M. javanica* indicated that most of the cultivars of the vegetables were susceptible (Tables 2-8). All the cultivars of eggplant and okra were susceptible to all the test nematodes. A few cultivars of tomato, pepper, cucumber, cauliflower and cabbage showed resistance to one or the other test nematode. Rest of the cultivars of these vegetables were also susceptible (Tables 2-8). Some of the cultivars which were reported resistant by earlier workers were also found susceptible. The variation in their reaction might be due to the difference in the levels of inoculum or difference in criteria used for separation of susceptible cultivars from resistant ones. The modified host suitability designations of Canto-Saenz (1983) which is based on actual nematode reproduction in the host and damage to the plant was developed as a standardized quantitative method and has been advocated to be used for such studies in order to promote increased uniformity of host-resistance designations (Sasser *et al.*, 1984). In the present investigations, this is for the first time in India that cultivars of some commonly grown vegetables have been screened against all the four races of *M. incognita* and *M. javanica* simultaneously and the latest host suitability designations for the cultivars have been assigned.

In the present study, ten cultivars of tomato were found immune and 3 cultivars resistant to all the 4 races of *M. incognita* and to *M. javanica* (Table 2). Some of the cultivars found immune or resistant in the present study were also reported resistant by earlier workers. VFN-8 was earlier reported as resistant to *M. incognita*; Race 1, Race 2 and Race 3 of *M. incognita* and

M. javanica (Singh, 1970; Ibrahim, 1982; Lamberti, 1983; Rajkumar and Krishnappa, 1984); VFN-Bush to M.incognita; Race 1, Race 3 of M. incognita and M. javanica (Ibrahim, 1982; Phukan, 1986; Nath, 1986); Kewalo to M. incognita and Race 1 of M. incognita (Fassuliotis, 1976; Sontirat, 1981; Valdez, 1981; Nath, 1986); Pelican to M. incognita and Race 1, Race 2, Race 3 of M..incognita (Hernandez et al., 1972; Rajkumar and Krishnappa, 1984); Panjab 6NR-7 to M. incognita (Nath, 1986); Calmart to M. incognita (Fassuliotis, 1976; Philis and Vakas, 1977). VFN-8 which was reported as susceptible to M. javanica by Sikora et al. (1973) was however, found immune to this species in the present study. The cultivars of tomato rated as susceptible or hypersusceptible are not suitable for cultivation in areas where either M. incognita (irrespective of races) or M. javanica are distributed. Some of the commonly grown cultivars of tomato like Pusa Ruby, Pusa Early Dwarf, Marglobe,Money Maker, Rutgers, Panjab Chhoara and Boney Best found susceptible have been reported susceptible by earlier workers as well (Varma, 1978; Patel, et al., 1979; Valdez, 1981; Yassin and Zeidan, 1982; Narayana and Reddy, 1983; Jain et al., 1983).

All the cultivars of eggplant tested were found susceptible to all the test nematodes (Table 3). Most of the popular and commonly grown cultivars like Pusa Purple Long, Pusa Kranti, Black Beauty, Pusa Purple Cluster, Long White, Baromashi, Benaras Giant, Purple Long, Manjari Gota and Round White were susceptible. Some of these cultivars were found susceptible in screening done by some workers earlier in India like Alam *et al*. (1974), Varma (1977), Upadhyay (1986) and Reddy *et al*. (1986). Some of the cultivars such as Gochha Baigan, Black Beauty, Muktakeshi, Long Purple, Improved Muktakeshi and Pusa Purple Long (Birat, 1966; Alam *et al*., 1974; Das, 1986; Reddy *et al*., 1986) which were claimed resistant were also susceptible in the present screening. The cultivars included in the present screening are not suitable for growing in *M. incognita* or *M. javanica* infested fields. There is a great need to develop cultivars of eggplant with resistance against all the 4 races of *M. incognita* and *M. javanica*.

All the cultivars of pepper were susceptible to all the 4 races of *M. incognita* except Jwala and Pusa Jwala. Jwala was found resistant to all the 4 races. However, Pusa Jwala was resistant to Race 1 and Race 3 only (Table 4). On the other hand, a number of cultivars were resistant to *M. javanica* while others were susceptible or hypersusceptible. Cultivar Pusa Jwala reported resistant to *M. incognita* by Das (1986) and Nath (1986) was found susceptible to Race 2 and Race 4. Some of the cultivars like Bull Nose, Chinese Giant, Hungarian Wax, Suryamukhi and California Wonder reported susceptible to *M. incognita* by Alam *et al*. (1974) were found susceptible to all the 4 races of *M. incognita*. California Wonder listed resistant to *M. javanica* by Taylor and Sasser (1978) exhibited resistance to *M. javanica* also in the present study.

The belief that *M. javanica* does not infect pepper is apparently not based on facts. There are some reports that evidently disprove it. Of 27 cultivars of pepper screened by Jain *et al.* (1983) against *M. javanica*, ten cultivars were found susceptible. A similar report was made by Walia and Gupta (1986) who found 34 cultivars out of 35 of chilli, they tested, susceptible to *M. javanica*. The results of the present study also supports their findings. Even during the survey in field plots, pepper crops were found infected (Section I. Tables 13, 18,23,28,33,38,43,48). A similar report has been made by Stephan (1988) from Iraq. This fact should be taken into account while growing pepper in *M. javanica* infested field plots or areas.

In okra, none of the cultivar tested showed resistance to either of the test nematodes (Table 5). A number of the cultivars included in the present study, were found susceptible to *M. incognita* and *M. javanica* in earlier studies (Alam *et al.*, 1974; Rao and Singh, 1977; Jain *et al.*, 1983; Thakar and Patel, 1985). The present study has revealed that these cultivars are not only susceptible to *M. javanica* and *M. incognita* but even to all the 4 races of *M. incognita* as well. In view of this, adequate management measures other than resistance are needed if such okra cultivars are to be grown in *M. incognita* or *M. javanica* infested soil.

In cucumber, except Improved Long Green, all the cultivars were found susceptible. Improved Long Green showed resistance against M. javanica and hypersusceptibility to Race 3 of M. incognita. Recently, Darekar et al. (1988) found all the 39 varieties of cucumber susceptible when screened against Race 3 of M. incognita. Some of the cultivars like All Season, Improved Long Green, Point Sett and Poona Kheera screened in the present study were also included in their test. In the United States, Winstead and Sasser (1956) screened 50 cucumber varieties and found all of them susceptible to M. incognita. There is a general lack of resistance in cucumber cultivars now being grown for root-knot nematodes. Improved Long Green have, however, found resistant to M. javanica can be utilized by growers for the fields infested with this species.

The reaction to cauliflower and cabbage cultivars used in the study varied according to the test nematode. Some exhibited race specific responses (Tables 7-8). A single cultivar of cauliflower Dania proved immune to all the test nematodes. Superial Maghi was immune to M. javanica. Cultivars 74-6C was found resistant to Race 1, and M. javanica; Pusa Snow Ball to Race 1 and Race 2; Massuria Snow Ball to Race 2; Balwan Snow Ball to Race 2; American White King (Vilayati) to Race 4; Early of India to Race 3 and Race 4; Indian Snow Ball to Race 2; Katki to Race 2; Pusa Late to Race 1; Early Market to Race 4; Suttons Pusi to Race 3. These cultivars were susceptible to rest of the test nematodes. Remaining cultivars were either susceptible or hypersusceptible (Table 7).

Of the 23 cabbage cultivars, only American Special Ball Head was resistant to all the test nematodes. Cultivar Red Drumhead was found resistant to Race 1, Race 2; Glory of Enkhuizen to Race 2, Race 3, Race 4; and Suttons Eclipse Drumhead to Race 1, Race 2, Race 4, M. javanica. These cultivars were susceptible to rest of the test nematodes. Remaining cultivars were either susceptible or hypersusceptible (Table 8).

As most of the cultivars of the vegetables were susceptible and some showed differential response being race specific, it would be desirable to desist from growing such cultivars in the root-knot infested areas. Additionally, before recommending the use of the cultivars that have shown differential response, it is greatly necessary to know the nature of infestation with regard to species and race content of the field or area to be grown and recommendations be made accordingly.

Host resistance is an importance natural source for use in the management of plant diseases including root-knot nematodes. Relatively a few cultivars that are commercially grown have shown resistance. The situation does not augur well for root-knot free cultivation of vegetables. Multiple species and multiple race infestation of the vegetables field plots further complicates the efforts and makes it more difficult to manage root-knot disease. Global efforts are needed to evolve cultivars of vegetables possessing multiple resistance against all the 4 major species and races of root-knot nematodes. Such efforts are being made for tomato at the The Asian Vegetable Research & Development Center (AVRDC), Taiwan. Other vegetables deserve similar attentions.

Wallace (1961), Veech (1981) and Huang (1985) have reviewed the mechanism(s) of resistance in plant against nematodes. Plants possess several types of defence mechanisms. Extrusion from plants of chemicals toxic to pathogens, preformed structures and chemicals that protect the plants from pathogens, synthesis of toxic substances, such as phytoalexins and building of physical barriers such as apposition of callose to cell walls are different kinds of attributes that resistant plants possess (Huang, 1985). Canto-Saenz (1985) in his brief review on the nature of resistance to M. incognita has enumerated a number of incompatible responses of resistant plants. He summarized that incompatible responses of resistant plants act through toxic exudates or by an effect on hatching, attraction or penetration of the roots by nematode. In some incompatible plants, the nematode either does not penetrate, or it penetrates for a short time, or in low numbers or in numbers equal to those penetrating compatible plants. After nematode penetration, several degrees of incompatibility have been reported. The most common response is hypersensitivity of the cells damaged by migrating juveniles or cells around the sedentary nematode. Some plants show no galling response, or galls may be small, inconspicuous or few in number (Canto-Saenz, 1985).

Incompatible plants are not always hypersensitive since in some cases, juveniles lie closely appressed and parallel to stele. Giant cells, if formed may be abnormal and not fully developed. In such cells, the nematode will develop poorly or slowly with no eggs or few eggs produced. Additionally, several biochemical mechanisms of incompatibility have also been implicated (Canto-Saenz, 1985). Sasser (1954) found that resistant plants were not penetrated as readily as susceptible plants. Dropkin and Webb (1967) observed that number of larvae of *M. hapla* in resistant tomato seedlings was much less than that in susceptible ones. In a histopathological study of soybean roots, Dropkin and Nelson (1960) noticed that roots of resistant plants had fewer nematodes than susceptible plants. Some experimental results indicate little difference in penetration of resistant and susceptible cultivars of alfalfa, cotton, tomato and snapbean by *Meloidogyne* spp. (Fassuliotis *et al.*,1970; Griffin and Elgin, 1977; Mc Clure *et al.*, 1974; Reynolds *et al.*, 1970; Riggs and Winstead, 1959). Huang (1985) stated that it is difficult to assess critically the importance of root surface as a barrier to nematode penetration. While reviewing the mechanisms of resistance to root-knot nematode, Huang (1985), however, cautioned that one must realise that resistance mechanimsm are complex and in many cases poorly understood.

In the present comparative study of juvenile penetration and post-penetration development of *M. incognita* (Race 1) and *M. javanica* in the roots of susceptible and resistant/immune cultivars of some vegetables, a marked difference in the rate of penetration in relation to time, total juvenile penetration, rate of development and attaining of maturity has been found.

In tomato cultivar, EC 173898 (72T6) which was found immune to both _M. javanica_ and _M. incognita_ Race 1 in screening, no juvenile penetration was noticed upto 15 days. After 30 days, a few juveniles were found in the roots but they did not develop further. Similarly, in pepper cultivar Jwala which was found immune to _M. javanica_, no juvenile penetration occurred. In resistant cultivars of cabbage and cauliflower which were included in the penetration study, an unequal juvenile penetration was noticed in comparison to susceptible cultivars. A significant difference existed in total juvenile penetration after 30 days. This was true for both the nematodes. A similar unequal penetration occurred in the cultivar of pepper resistant to _M. incognita_ Race 1 and in the cultivar of cucumber resistant to _M. javanica_ in comparison to their respective susceptible cultivars.

The juveniles of _M. incognita_ Race 1 that penetrated the resistant cultivar of pepper did not show normal course of development. Only a few (5) could attain maturity and developed into adult females. Rest of the penetrated juveniles remained in J_2 stage or a few developed into J_3/J_4. In the resistant cultivars of cabbage and cauliflower, juveniles of _M. incognita_ Race 1 and _M. javanica_ that could make ingress also did not show proper growth. None could develop into females and only a few reached upto J_3/J_4 till the observation were made.

In the resistant cultivar of cucumber, penetration was slightly greater than in the resistant cultivars of other vegetables. In roots of the resistant cultivar of cucumber, a high percentage of juveniles matured into females. Females, however, were dimunitive and abnormal in shape. These results have clearly demonstrated that a difference existed between resistant and susceptible cultivars of vegetables for penetration and development of juveniles of root-knot nematodes. Singh and Reddy (1985) also demonstrated in cowpea that in resistance cultivar larval invasion was poor; root galling, eggmass production and fecundity was reduced and development of females was delayed.

Without implicating any specific mechanism(s) responsible for the differences that has been noticed both in pre- and post-penetration stages of juveniles in resistant and susceptible cultivars, it can be surmized that some factors at both the stages acted as barrier for the penetration and development of the root-knot nematodes.

SUMMARY

Cultivars of some vegetable crops like tomato, eggplant, pepper, okra, cucumber, cauliflower and cabbage were screened against *M. javanica* and Race 1, Race 2, Race 3 and Race 4 of *M. incognita* in order to evaluate their degree of resistance. In addition, a comparative assessment of penetration and post-penetration development of juveniles of *M. javanica* and *M. incognita* Race 1 in the roots of susceptible and resistant cultivars of some vegetable crops was made.

Most of the cultivars of the vegetables screened were susceptible to all the test nematodes. All the cultivars of eggplant and okra were susceptible to all the test nematodes. Some cultivars of tomato, pepper, cucumber, cauliflower and cabbage, however, showed resistance to one or the other test nematode.

Of thirty six cultivars of tomato screened, ten viz., Pusa-120, Calmart VFN, Panjab 6.NR-7, EC173898 (72T6), EC173897 (Cal-Mart), EC173896 (Kewalo), CLN363BC$_1$F$_2$-167-1-0, CLN363BC$_1$F$_2$-190-1-0, CLN363BC$_1$F$_2$-344-0-0 and CLN229BC$_1$F$_2$-4-1-4-0 were found immune and 2 viz., VFN-Bush and VFN-8 resistant to all the test nematodes. Pelican was rated as resistant to Race 1, Race 2, Race 4; tolerant to Race 3 and immune to *M. javanica*. In pepper, out of the 14 cultivars included in the test, 12 were susceptible to all the 4 races of *M. incognita*. Two cultivars,

Jwala and Pusa Jwala showed resistance. Jwala was resistant to all the 4 races; but Pusa Jwala was resistant to Race 1 and Race 3 only. Against M. javanica, five cvs., Jwala, Bull Nose, Chinese Giant, Chilli N-P.46-A and Suryamukhi were immune and other five cvs., Pusa Jwala, Suryamukhi Black, Hungarian Wax, Chilli G-3 and California Wonder were resistant.

None of the 10 cultivars of okra and 19 of eggplant screened showed resistance to either of the test nematodes. In cucumber, except Improved Long Green all the 9 cultivars were found susceptible. Improved Long Green showed resistance to M. javanica and hypersusceptibility to Race 3 of M. incognita.

The reaction of 37 cultivars of cauliflower used in the study varied according to the test nematode. A number of cultivars were resistant to one or the other test nematode. Three cultivars namely 74-6C, Pusa Snow Ball and Pusa Late were resistant to Race 1 of M. incognita. To Race 2, Pusa Snow Ball, Massuria Snow Ball, Balwan Snow Ball, Indian Snow Ball and Katki, and to Race 3, Early of India and Suttons Pusi were resistant. To Race 4, American White King (Vilayati), Early of India and Early Market were resistant and 74-6C and Pusa Snow Ball were tolerant. All other cultivars were susceptible or hypersusceptible to M. incognita races. To M. javanica, 74-6C was resistant and Superial Maghi was immune. Rest of the cultivars were either susceptible or hypersusceptible. A single cv. Dania was immune to all the test nematodes. In cabbage, 23 cultivars were screened. American Special Ballhead, Red Drumhead and Suttons Eclipse Drumhead were resistant to Race 1; American Special Ballhead, Glory of Enkhuizen and Suttons Eclipse Drumhead to Race 2; Red Drumhead and Glory of Enkhuizen to Race 3; and American Special Ballhead, Glory of Enkhuizen and Suttons Eclipse Drumhead to Race 4 of *M. incognita*. American Special Ballhead was immune to Race 3. Rest of the cultivars were susceptible or hypersusceptible. American Special Ballhead and Suttons Eclipse Drumhead were resistant to *M. javanica*. Other cultivars tested were susceptible and a few were hypersusceptible to *M. javanica*.

In the comparative study of juvenile penetration and post-penetration development of *M. incognita* (Race 1) and *M. javanica* in roots of susceptible and resistant/immune cultivars of some vegetables, a marked significant difference in the rate of penetration in relation to time, total juvenile penetration, rate of development and attaining of maturity was found. Root penetration by juveniles of both the nematodes in resistant/immune cultivars was significantly poor in contrast to susceptible cultivars of the vegetables.

In tomato cultivars EC173898 (72T6) immune to both *M. javanica* and *M. incognita* Race 1, a few juvenile penetrated. In contrast, in a susceptible cv. Pusa Ruby a greater number of juvenile penetrated. In pepper, cv. Jwala immune to *M. javanica*, no penetration occurred. Unequal penetration occurred in cv. Jwala of pepper found resistant to *M. incognita* Race 1 in comparison to susceptible cultivar, Suryamukhi Green. Similarly, in cucumber cv. Improved Long Green resistant to *M. javanica*, poor penetration of juveniles occurred in comparison to its susceptible cv. Point Sett. In resistant cultivars of cabbage (Suttons Eclipse Drumhead) and cauliflower (74-6C), an unequal juvenile penetrations were noticed in comparison to susceptible cvs. Pride of Asia and Snow Ball No.16 respectively. This was true for both the nematodes.

The juveniles of *M. incognita* Race 1, or *M. javanica* that penetrated the resistant cultivars of vegetables did not show normal course of development. Their development was delayed and a few juveniles matured into adults. Therefore, a difference existed between resistant and susceptible cultivars of vegetables for penetration and development of juveniles of root-knot nematodes.

SECTION III

INTRODUCTION

The soil salinity is one of the important ecological stresses. Saline soils contain variable amounts of cations and anions at different concentrations and complexities. The common dominant anions are chlorides (Cl^-)sulphites (SO_3^{2-}), bicarbonates (HCO_3^-) and sometimes nitrate (NO_3^-). The cations are calcium (Ca^{2+}), sodium (Na^+), magnesium (Mg^{2+}) and sometimes potassium (K^+). These elements can exist individually or in combination with others to form complex compounds (Edongali et al., 1982). The soil and the chemical composition of the soil solution directly affect both plants and nematodes as well as nematode eggs in the soil.

Salinity is known to have adverse effects on plant growth and metabolism (Ungar, 1974; Weimberg, 1975). Deleterious effects of saline conditions on plant growth, in general, are attributed to two main factors viz., increase in osmotic pressure of rooting medium and specific ion effects (Bernstein and Hayward, 1958; Strogonov, 1962). The extent of injury done to plants by salinization of the medium varies with the type of the predominant ions, their concentration, the physiological stage of plant growth at which it is exposed to salinity and the plant species (Strogonov, 1962; Weimberg, 1975). Sheoran and Garg (1978) observed the germination and early seedling growth in different salinity condition of NaCl, KCl, Na_2SO_4 and K_2SO_4. They found delayed germination and growth inhibition of seedlings with independent of the type of salinity. Maliwal and Paliwal (1967) reported that soil salinity suppress the plant growth from germination to maturity. Parihar and Baijal (1982) observed that the protease activity decreases with increasing salinity level, the degree of inhibition varied with the variety. The susceptible variety show maximum inhibition as compared to the tolerant variety.

There is also an indirect influence on plant nematodes living within plant tissues that results from the effect of salinity on plant growth (Dropkin *et al*., 1958; Kirkpatrick and Van Gundy, 1966; Bernstien, 1959; Everard, 1960). Dropkin *et al*. (1958) found that the larvae of *M. javanica* failed to emerge from eggs kept in dilute fertilizer solutions. Machmur (1958) found, under field conditions, more citrus nematode and other nematodes around citrus roots subjected to high salinity levels than around citrus roots grown at lower salinity levels. He observed that the various species of nematodes were not affected by salinity levels which were used in the experiment. Van Gundy and Martin (1961) observed a little change in mineral content of the citrus plant infected by the citrus nematode when grown in acid soils, but considerably affected in alkaline soils containing high amounts of sodium or calcium carbonate. The citrus nematodes was reduced in number at pH values of 4.3 and 3.3, but not at pH values of 5.6–7.6. Kirkpatrick and Van Gundy (1966) also obtained more citrus nematodes from citrus roots subjected to high salinity than from citrus growing at low salinity levels.

Nematodes may interact with salinity in their effect on the plant. Heald and Heilman (1971) found that *Rotylenchulus reniformis* occurred in similar numbers in relatively non-saline and in highly saline soils in Texas cotton field. Nevertheless, glasshouse experiments indicated that nematode injury increased as the soil salinity increased. Maggenti and Hardan (1973) salinized a non-sodic, non-saline sandy loam soil to anion cation ratios similar to those naturally occurring in Iraq and California. And interactions of saline soil with a moderately salt-tolerant tomato plant cv. 'Marimond' and *M. javanica* were investigated. The nematode demonstrated an important modifying influence within the plant environment, either accentuating or ameliorating salinity stress effects.

In India Lal and Yadav (1975) surveyed for incidence of plant parasitic nematodes in saline soils of Rajasthan. The incidence of root-knot nematode was generally low in such soils. Soil leachates of varying salt concentrations, inhibited hatching of eggs of *M. incognita*. When the eggmasses from different salinity levels were transferred to double distilled water at the end of 10 days the hatching revival was noticed, indicating that the salt concentrations used had inhibitory rather than killing effect. The inhibitory effect was claimed due to presence of chloride salts of calcium and sodium. Similarly, Ray and Das (1980) surveyed for plant parasitic nematodes in saline soils of two district (Cuttack and Puri) of Orissa. They found that many species of *Tylenchus*, *Tylenchorhynchus*, *Pratylenchus* and

Aphelenchoides were tolerant to slightly saline soil conditions (2-4 mmhos/cm) while species like *Helicotylenchus dihystera*, *Hirschmanniella gracilis* and *Macroposthonia ornata* thrived well in moderately saline soils with ECs around 6 mmhos/cm. A few other nematodes like *Rotylenchulus reniformis*, *Macroposthonia sphaerocephala*, *Hemicriconemoides cocophillus* and *Caloosia exilis* tolerated strongly saline soil conditions (10.25 mmhos/cm).

In artificial condition interactive effect of soil salinity and root-knot nematodes on host performance has been studied by some workers. Edongali and Ferris (1980) found that the interaction of salinity and *M. incognita* resulted in less Na^+ in leaves and roots of several cultivars of tomato. Edongali and Ferris (1980) and Edongali *et al.* (1982) reported that increasing soil solution concentration of NaCl and $CaCl_2$ impaired the infectivity and development of *M. incognita* on tomato. Reduced infectivity was pronounced on a susceptible cultivar at all salt concentrations, while infectivity was reduced primarily at higher salt concentrations on a moderately resistant cultivar. Development of the nematode was significantly depressed on susceptible cultivar whereas it was delayed on moderately resistant one. Impaired infectivity and development resulted in population reduction of the nematode.

As indicated in general introduction, soil salinity is a serious problem in some areas in India including Uttar Pradesh. But studies pertaining to the effect of soil salinity on root-knot nematodes and the interactive effects of soil salinity and root-knot nematodes on crops grown are very few. Therefore, an attempt has been made to study some of these aspects selecting *M. javanica* and *M. incognita*, the two common species of the area and cucumber and okra as test crops under artificially created salinity levels using $NaHCO_3$ and NaCl.

MATERIALS AND METHODS

Effects of soil salinity levels on hatching and mortality of root-knot nematodes and their penetration and development within the host roots were studied under artificail conditions. *M. javanica* and *M. incognita* Race 2 were selected as test nematodes for the study. Cucumber cv. Point Sett and okra cv. Pusa Sawani susceptible to both, *M. javanica* and *M. incognita* Race 2 were selected as test plants. Salts of sodium, sodium chloride and sodium bicarbonate were used to create salinity levels. The combined effect of the soil salinity levels and the nematodes on plant growth at both the crops was also determined in artificial treatments.

Preparation of stock solution :

Stock solution (1000 mmhos/cm) of sodium chloride (NaCl) and sodium bicrabonate ($NaHCO_3$) were prepared by dissolving gram molecular weight of sodium chloride (58.44g) and of sodium bicarbonate (84.01g) in 1000 ml distilled water. Solutions of different concentrations for the salinity levels viz., 1.5, 2.5, 3.5 and 5.0 mmhos/cm used in the experiments were prepared by adding requisite quantity of distilled water in 1.5, 2.5, 3.5 and 5.0 ml of stock solution to make the total valume 1000 ml respectively.

Hatching and mortality :

To study the effect on juvenile hatching, 10 ml of each concentration (1.5, 2.5, 3.5 and 5 mmhos/cm) of NaCl and $NaHCO_3$ were transferred separately to two separate sets of 40 mm petridishes. Each set one for NaCl and other $NaHCO_3$, consisted of 30 petridishes, 15 petridishes for *M. javanica* and 15 for *M. incognita* Race 2. Petridishes in each set were added separately with 5 average sized eggmasses of *M. javanica* and *M. incognita* Race 2 (3 petridishes/salt/concentration/nematode). Petridishes added with sterilized water served as control. The petridishes were then incubated at $20 \pm 2°C$ temperature. Total hatched juveniles were counted after a week and per cent inhibition over control was calculated.

To study the juvenile mortality, 5 ml of double strength of each concentration of NaCl and $NaHCO_3$ were taken separately in each of the 2 sets of petridishes (40 mm). Each set, one for NaCl and other for $NaHCO_3$ consisted of 120 petridishes, 60 for *M. javanica* and 60 for *M. incognita* Race 2. Five ml suspension containing 100 freshly hatched juveniles of *M. javanica* or *M. incognita* Race 2 was transferred to each petridish separately. Petridishes receiving only distilled water (without salt) served as control. Each treatment was replicated thrice. The petridishes were kept at $20 \pm 2°C$ temperature. Number of immobile juveniles were counted at different time intervals (24, 48, 72 and one week) from each petridish and per cent mortality was calculated.

Penetration :

For studying the effect of salinity levels on penetration of *M. javanica* juveniles in cucumber roots, seeds of cucumber (cv. Point Sett) were sown in paper cups (8 cm) each containing 100 g thoroughly washed river sand. When the seedlings were in 3-leaf-stage (one seedling/cup) 25 ml solution of different concentrations (0.0, 1.5, 2.5, 3.5 and 5.0 mmhos/cm) of NaCl and $NaHCO_3$ were added separately in 5 replicate cups for each concentration of both the salts (5 cups/conc./salt/nematode/time interval). This quantity (25 ml) was found sufficient to moisten the sand. The cups were then inoculated with 1000 freshly juveniles of *M. javanica* and maintained at room temperature. Seedlings were uprooted at different time intervals i.e. 24, 48, 72h and one week after inoculation. Total number of individuals of the nematode present in the roots were counted after staining the roots with acid fuchsin and percentage penetration was calculated. Likewise an experiment following the same methods was conducted to determine the effect of salinity levels on penetration of *M.javanica* in okra (cv. Pusa Sawani) roots.

Similar experiments were also conducted for studying the penetration of *M. incognita* Race 2 juveniles in cucumber and okra roots under different salinity levels of both the salts as done for *M. javanica*.

Development of the nematodes and plant growth :

The effect of soil salinity on the development of *M. javanica* and plant growth of cucumber (cv. Point Sett) was studied in artificial treatments. In this study, 2 different concentrations (3.5, 5.0 mmhos/cm) of NaCl and $NaHCO_3$ were used. Plants of cucumber were grown in 15 cm plastic pots filled with 1 kg thoroughly washed sand and autoclaved soil (80% sand + 20% soil). The salinity levels were maintained by adding 250 ml solution of different concentrations (0.0, 3.5 and 5.0 mmhos/cm) of NaCl and $NaHCO_3$. Seedlings of cucumber 3-leaf-stage (one seedling/pot) were inoculated with freshly hatched juveniles (J_2) of M. javanica (1000 J_2/pot). All the treatments were replicated five times (5 pots/concentration/salt/time interval). Pots were kept on glasshouse benches in randomised block design. Five plants were uprooted every week for six weeks from each treatment. Number of eggmasses produced on the roots were counted. Roots were then stained with acid fuchsin and examined to determine the number of different developmental stages of the nematode. The stages included in counting the number were second stage juveniles, third/fourth stage juveniles, pre-mature females and mature females.

Six weeks after inoculations, a set of plants from each treatment were harvested and plant growth parameters like length, fresh and dry weights of root and shoot and total dry weight were determined. Gall index (GI) and eggmass index (EMI) were also rated (Taylor and Sasser, 1978). A similar experiment following the same methods was conducted to determine the effect of salinity levels on development of M. javanica and plant growth of okra (cv. Pusa Sawani).

Similar experiments were also couducted for studying the development of *M. incognita* Race 2 and growth of cucumber and okra plants under different salinity levels of both the salts, as done for *M. javanica*.

Data were analysed statistically for significance.

RESULTS

Effects of different concentrations of NaCl and $NaHCO_3$ as soil salinity levels on hatching and mortality of juveniles (J_2) of *M. javanica*, *M. incognita* Race 2 and on their penetration and development within the host roots of cucumber and okra were studied in artificial conditions. The combined impact of the soil salinity levels and the nematodes on plant growth of both the crops was also assessed.

Effect on hatching and mortality :

a. *M. javanica* :-

The data presented in Table 1 and Figs. 1 and 2 indicate that all the concentrations of $NaHCO_3$ inhibited juveniles hatch and induced their mortality. A gradual increase in per cent inhibition of juvenile hatching was noticed with an increase in salinity levels. Highest inhibition of hatching among the concentrations used was obtained with 5.0 mmhos/cm. This was 59.69% over control.

All the concentrations of $NaHCO_3$ induced juvenile mortality. The per cent mortality was concentration dependent. Per cent mortality of juveniles (J_2) gradually increased in all the concentrations with an increase in the exposure periods. A linear correlation between different concentrations of $NaHCO_3$ and per cent mortality of juveniles was found for each exposure period (Table 1, Figs. 1 and 2).

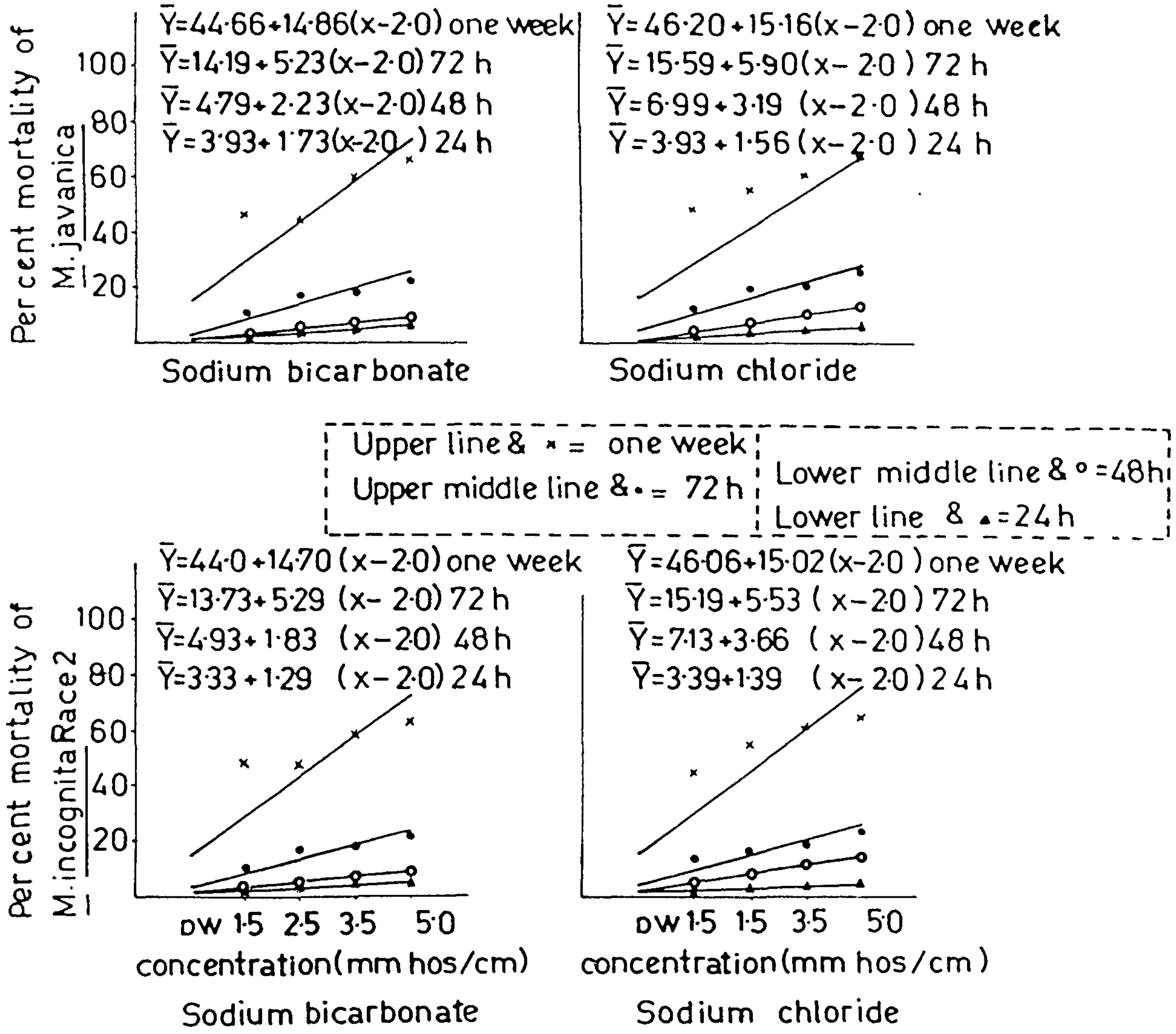


Fig.1: REGRESSION LINES SHOWING LINEAR RELATIONSHIPS BETWEEN DIFFERENT CONCENTRATIONS OF NaCl, $NaHCO_3$ AND PER CENT MORTALITY OF JUVENILES (J_2) OF ROOT-KNOT NEMATODES.

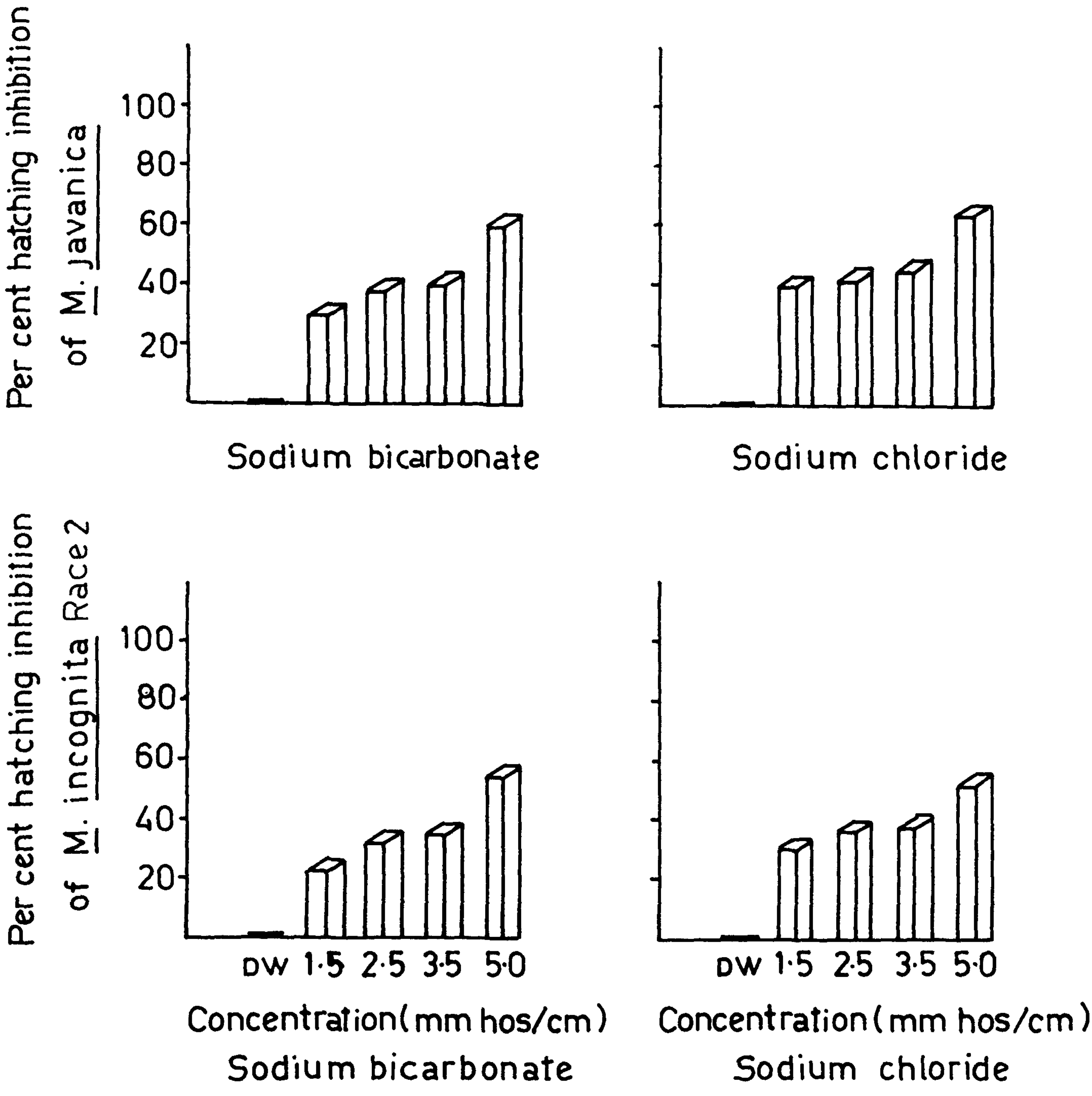


Fig. 2: JUVENILE HATCHING INHIBITION (OVER CONTROL) OF ROOT-KNOT NEMATODES IN DIFFERENT CONCENTRATIONS OF $NaHCO_3$ AND NaCl .

Table 1. Hatching and mortality of *Meloidogyne javanica* in different concentrations of sodium bicarbonate and sodium chloride.

Concentration mmhos/cm	Mortality (%)				Hatching
	Exposure period (h)				% inhibition
	24	48	72	1 week	
Sodium bicarbonate					
0.0	0	0	0	0	-
1.5	2.33	2.66	12.33	46.33	30.13
2.5	4.66	5.00	17.33	51.33	37.81
3.5	5.66	7.66	18.00	59.66	39.59
5.0	7.00	8.66	23.33	66.00	59.69
Sodium chloride					
0.0	0	0	0	0	-
1.5	3.00	5.00	12.66	48.00	39.80
2.5	4.66	6.33	19.00	55.00	42.97
3.5	5.33	10.33	21.00	60.00	45.04
5.0	6.66	13.33	25.33	68.00	64.55

A similar trend in the effects of different concentrations of NaCl on juvenile hatching and mortality of M. javanica was found. But hatching inhibition and mortality of juveniles in the concentrations of NaCl were slightly greater than $NaHCO_3$. Highest per cent inhibition over control in hatching was 64.55 in NaCl as compared to 59.69 in $NaHCO_3$ at 5.0 mmhos/cm. After a week, mortality was also 68% in NaCl as compared to 66% in $NaHCO_3$ (Table 1, Figs. 1 and 2).

b. M. incognita Race 2 :-

As for M. javanica, the concentrations of $NaHCO_3$ and NaCl adversely affected the juvenile hatch and induced mortality of the juveniles of M. incognita Race 2 as well. All the concentrations of $NaHCO_3$ inhibited juvenile hatch and induced their mortality. A direct correlation between the concentrations and per cent juvenile hatch was observed. The per cent mortality of juveniles also showed a linear correlation with the concentration for each exposure period as in case of M. javanica. After a week, the hatching inhibition and mortality of juveniles were 57.74% and 64.00% respectively at 5.0 mmhos/cm (Table 2, Figs. 1 and 2).

The concentrations of NaCl also showed similar effects in inhibiting hatching and inducing mortality of juveniles of M. incognita Race 2. Greater exposure period and higher concentration showed a direct bearing on killing the juveniles and

Table 2. Hatching and mortality of <u>Meloidogyne incognita</u> Race 2 in different concentrations of sodium bicarbonate and sodium chloride.

Concentration (mmhos/cm)	Mortality (%) Exposure period (h)				Hatching
	24	48	72	1 week	% inhibition
<u>Sodium bicarbonate</u>					
0.0	0	0	0	0	-
1.5	2.33	4.00	10.33	48.00	23.57
2.5	4.33	6.33	16.66	49.00	31.59
3.5	4.66	6.33	18.33	59.00	34.72
5.0	5.33	8.00	23.33	64.00	57.74
<u>Sodium chloride</u>					
0.0	0	0	0	0	-
1.5	2.33	4.00	14.33	47.33	30.70
2.5	4.00	6.00	16.66	55.00	35.80
3.5	5.00	10.66	20.33	61.00	37.19
5.0	5.66	15.00	24.66	67.00	61.59

inhibiting their hatch. Highest hatching inhibition (61.59%) was noticed in 5.0 mmhos/cm after a week. Similarly, highest mortality percentage (67%) was observed in 5.0 mmhos/cm after a week (Table 2, Figs. 1 and 2). Sodium chloride was more effective in these respects than $NaHCO_3$ for M. incognita Race 2 too.

Penetration of juveniles in cucumber :

a. M. javanica :-

Penetration of M. javanica juveniles was impaired in cucumber roots treated with $NaHCO_3$. The per cent juvenile penetration was reduced with an increase in the concentration at all the time intervals. The reduction in penetration in all the concentrations was significant in comparison to control at both $P = 0.05$ and $P = 0.01$ at all the time interval except 24 and 48 h, where, in 1.5 mmhos/cm, it was significant only at $P = 0.05$ (Table 3). After a week, in 5.0 mmhos/cm only 22.3% juveniles could make their ingress in roots in comparison to 38.9% in control (Table 3).

A similar trend of reduction in penetration of M. javanica juveniles in cucumber root treated with NaCl was also observed. The reduction was significant in all the concentrations at all the time intervals both at $P = 0.05$ and $P = 0.01$ except at 24 h, where in 1.5 mmhos/cm, it was not significant. They differed from control at both levels (Table 3). After a week, in 5.0 mmhos/cm, per cent juvenile penetration was 23% in comparison to 38.9% in

Table 3. Influence of sodium bicarbonate and sodium chloride on juvenile penetration of Meloidogyne javanica in cucumber roots, cv. Point Sett.

Concentration (mmhos/cm)	Time period (h)			
	24	48	72	1 week
Sodium bicarbonate				
0.0	17.8	29.4	32.0	38.9
1.5	13.6	21.1	26.3	30.0
2.5	13.0	20.2	22.2	27.0
3.5	12.6	15.9	18.8	26.8
5.0	9.3	13.7	16.4	22.3
L.S.D.(P=0.05)	3.29	7.54	2.33	2.37
L.S.D.(P=0.01)	4.78	10.97	3.39	3.46
Sodium chloride				
0.0	17.8	29.4	32.0	38.9
1.5	16.4	20.1	26.0	29.5
2.5	10.8	16.1	17.7	27.0
3.5	10.1	14.6	15.1	26.0
5.0	9.4	12.4	13.1	23.0
L.S.D.(P=0.05)	2.26	3.90	2.73	4.23
L.S.D.(P=0.01)	3.25	5.68	3.98	6.16

control (Table 3).

b. *M. incognita* Race 2 :-

Juvenile penetration of *M. incognita* Race 2 in cucumber roots was also reduced by all the concentrations of $NaHCO_3$. With an increase in concentration of $NaHCO_3$, a corresponding decrease in penetration was found at all the time intervals. This reduction was significant for all the concentrations in comparison to control at all the time intervals both at P = 0.05 and P = 0.01 except at 24 and 48 h, where it was significant only at P = 0.05 (Table 4). After a week, in 5.0 mmhos/cm juvenile penetration was 23.9% in comparison to 43.1% in control (Table 4).

A similar trend of reduction in penetration of *M. incognita* Race 2 juveniles in cucumber root treated with NaCl was also observed. The reduction was significant in all the concentration at all the time intervals. In 5.0 mmhos/cm, juvenile penetration was 23.6% in comparison to 43.1% in control when observed after a week (Table 4).

Penetration of juveniles in okra :

a. *M. javanica* :-

Penetration of *M. javanica* juvenile was significantly reduced in okra root treated with the different concentrations of $NaHCO_3$ when compared with control. At all the time intervals with an increase in concentration of $NaHCO_3$, a corresponding

Table 4. Influence of sodium bicarbonate and sodium chloride on juvenile penetration of _Meloidogyne incognita_ Race 2 in cucumber roots, cv. Point Sett.

Concentration (mmhos/cm)	Time period (h)			
	24	48	72	1 week
Sodium bicarbonate				
0.0	17.9	31.1	36.9	43.1
1.5	15.6	29.2	31.4	35.0
2.5	12.7	18.6	22.2	30.4
3.5	12.0	17.7	22.3	27.0
5.0	10.7	16.0	21.3	23.9
L.S.D.(P=0.05)	1.94	2.81	2.12	3.45
L.S.D.(P=0.01)	2.83	4.09	3.09	5.03
Sodium chloride				
0.0	17.9	31.1	36.9	43.1
1.5	13.6	22.6	27.9	32.2
2.5	12.2	18.4	22.9	29.5
3.5	11.9	14.6	18.4	24.9
5.0	10.5	12.9	15.9	23.6
L.S.D.(P=0.05)	1.37	2.43	3.13	3.17
L.S.D.(P=0.01)	2.00	3.54	4.56	4.62

reduction in penetration occurred. After a week, in 5.0 mmhos/cm 31.2% juvenile penetrated the roots as compared to 50.3% in control (Table 5).

Different concentrations of NaCl also caused a similar trend of reduction in penetration of *M. javanica* juveniles in okra roots. A significant reduction in penetration was observed in all the concentration at all the time intervals both at P=0.05 and P=0.01 levels except 72h, where,it was significant only at P=0.05. In 5.0 mmhos/cm, after a week, the ingress of juveniles was 28% in comparison to 50.3% in control (Table 5).

b. *M. incognita* Race 2:-

A reduction in root penetration of okra by juveniles of *M. incognita* Race 2 occurred due to treatment of $NaHCO_3$. All the concentration used were effective at all the time intervals in causing significant reduction in juvenile penetration when compared with control. After a week, in 5.0 mmhos/cm 30% juvenile penetration was noticed in comparison to 51.5% in control (Table 6).

A significant reduction in penetration of *M. incognita* Race 2 juveniles in okra roots treated with NaCl was also observed in all the concentrations over control at all the time intervals. The percentage of juvenile penetration was 28.5 in 5.0 mmhos/cm after a week as compared to 51.5 in control (Table 6).

Table 5. Influence of sodium bicarbonate and sodium chloride on juvenile penetration of *Meloidogyne javanica* in okra roots, cv. Pusa Sawani.

Concentration (mmhos/cm)	Time period (h)			
	24	48	72	1 week
Sodium bicarbonate				
0.0	20.0	31.0	38.0	50.3
1.5	15.0	20.9	32.7	41.6
2.5	13.0	18.5	20.4	37.6
3.5	12.5	17.8	19.7	33.7
5.0	12.0	14.4	16.6	31.2
L.S.D.(P=0.05)	1.13	1.61	4.31	4.76
L.S.D.(P=0.01)	1.65	2.35	6.28	6.83
Sodium chloride				
0.0	20.0	31.0	38.0	50.3
1.5	16.0	19.6	30.6	40.6
2.5	13.5	18.4	20.5	36.3
3.5	13.2	16.1	19.7	30.2
5.0	12.4	14.2	15.7	28.0
L.S.D.(P=0.05)	1.09	2.74	5.85	6.36
L.S.D.(P=0.01)	1.60	3.99	8.51	9.26

Table 6. Influence of sodium bicarbonate and sodium chloride on juvenile penetration of <u>Meloidogyne incognita</u> Race 2 in okra roots, cv. Pusa Sawani.

Concentration (mmhos/cm)	Time period (h)			
	24	48	72	1 week
<u>Sodium bicarbonate</u>				
0.0	18.5	32.4	40.9	51.5
1.5	16.0	20.0	30.0	39.0
2.5	13.5	19.0	25.2	34.2
3.5	12.7	18.5	20.5	33.0
5.0	12.2	15.0	18.2	30.0
L.S.D.(P=0.05)	0.56	1.09	2.07	1.84
L.S.D.(P=0.01)	0.81	1.59	3.01	2.64
<u>Sodium chloride</u>				
0.0	18.5	32.4	40.9	51.5
1.5	15.2	20.4	29.0	36.5
2.5	13.0	19.5	23.1	33.3
3.5	12.4	18.2	20.0	31.0
5.0	11.8	14.2	19.5	28.5
L.S.D.(P=0.05)	0.48	0.48	1.00	3.83
L.S.D.(P=0.01)	0.70	0.71	1.46	5.58

Development of juveniles in cucumber :

a. M. javanica :-

Results presented in Table 7 show that development of juveniles of M. javanica into adults and production of eggmasses by females were delayed in roots treated with different concentrations of $NaHCO_3$. After one week, the number of juveniles into J_3/J_4 stage was lower in roots treated with 3.5 and 5.0 mmhos/cm than in roots of untreated (control) plants. A number of juveniles developed into mature females in control and 3.5 mmhos/cm concentration after two weeks. But the number of mature females in control was greater than in 3.5 mmhos/cm. In 5.0 mmhos/cm, however, juveniles could develop only into premature female stage during this period. Development of mature females and eggmass production were observed after three weeks. The number of mature females and eggmass increased gradually in all the treatment with lapse of time (upto six weeks). In general, a delay in development of juveniles into females and eggmass production was noticed by treatments with both the concentrations of $NaHCO_3$. In roots treated with $NaHCO_3$ concentrations, a significantly lower number of juveniles matured into females and comparatively less number of eggmasses were produced when compared with control at all the intervals of observations (3, 4, 5 and 6 weeks). In general, no significant difference between the two concentrations with respect to their effects on development of juveniles and eggmass production was observed.

Table 7. Effect of sodium bicarbonate on the development of *Meloidogyne javanica* on cucumber cv. Point Sett.

Time (week)	Concentration (mmhos/cm)	Stage of development				
		J_2	J_3/J_4	P♀	M♀	EM
One	0.0	170	304	5	-	-
	3.5	193	225	-	-	-
	5.0	152	164	-	-	-
L.S.D.(P=0.05)		34.5	60.0			
L.S.D.(P=0.01)		57.2	99.5			
Two	0.0	32	255	151	62	-
	3.5	132	241	93	13	-
	5.0	194	235	38	-	-
L.S.D.(P=0.05)		38.3	28.1	39.1		
L.S.D.(P=0.01)		63.5	46.6	65.0		
Three	0.0	32	153	-	248	62
	3.5	46	192	-	142	21
	5.0	87	220	-	111	8
L.S.D.(P=0.05)		31.0	29.1		15.3	9.6
L.S.D.(P=0.01)		51.4	48.3		25.4	15.8
Four	0.0	-	147	-	317	88
	3.5	-	191	-	272	29
	5.0	-	266	-	176	18
L.S.D.(P=0.05)			14.4		22.3	14.8
L.S.D.(P=0.01)			23.9		37.0	24.6
Five	0.0	14	29	-	479	115
	3.5	-	84	-	352	80
	5.0	-	149	-	286	56
L.S.D.(P=0.05)			10.5		54.3	20.7
L.S.D.(P=0.01)			17.4		90.1	34.3
Six	0.0	432	130	12	473	170
	3.5	222	121	-	383	83
	5.0	172	50	-	358	63
L.S.D.(P=0.05)		43.4	27.6		43.5	54.7
L.S.D.(P=0.01)		71.9	45.9		72.1	90.7

J= Juveniles, P♀=Premature females, M♀=Mature females, EM=Eggmass

Similar results were obtained when cucumber plants were treated with sodium chloride except that no production of eggmass was found in 5.0 mmhos/cm after three weeks (Table 8).

b. M. incognita Race 2 :-

Treatment of cucumber plants with $NaHCO_3$ delayed the development of M. incognita Race 2 as well. In one week, juveniles developed into J_3/J_4 and premature stages in treated and untreated (control) roots. But number of J_3/J_4 was comparatively less in 3.5 or in 5.0 mmhos/cm than in control. After two weeks, a number of juveniles developed into mature females in all the treatments including control. But the number of mature females differed in treated and untreated plants. After three weeks, eggmass production was observed only in untreated (control) plants. The number of females and eggmasses gradually increased with passage of time. A significant reduction in the number of mature females and eggmasses occurred in both the treatments of $NaHCO_3$ in comparison to control. Development of females and eggmass production was delayed in general by application of $NaHCO_3$ (Table 9).

M. incognita Race 2 responded similarly when the plants were treated with sodium chloride. Development of females and eggmass production was significantly reduced in both the treatments of NaCl in comparison to control (Table 10).

Table 8. Effect of sodium chloride on the development of *Meloidogyne javanica* on cucumber cv. Point Sett.

Time (week)	Concentration (mmhos/cm)	State of development J_2	J_3/J_4	P♀	M♀	EM
One	0.0	176	294	5	-	-
	3.5	192	280	-	-	-
	5.0	145	147	-	-	-
L.S.D.(P=0.05) L.S.D.(P=0.01)		29.1 48.3	59.0 98.0			
Two	0.0	40	270	154	37	-
	3.5	184	240	30	6	-
	5.0	160	161	25	7	-
L.S.D.(P=0.05) L.S.D.(P=0.01)		22.4 37.2	39.6 65.7	21.1 35.0	6.5 10.8	
Three	0.0	10	185	-	280	45
	3.5	125	135	-	135	19
	5.0	157	140	-	64	-
L.S.D.(P=0.05) L.S.D.(P=0.01)		11.3 18.8	28.5 47.2		9.9 16.5	
Four	0.0	-	168	-	350	75
	3.5	50	112	70	240	36
	5.0	-	235	20	165	12
L.S.D.(P=0.05) L.S.D.(P=0.01)			25.0 41.4		47.1 78.2	8.2 13.7
Five	0.0	20	7	-	496	125
	3.5	-	40	-	331	75
	5.0	-	164	-	200	45
L.S.D.(P=0.05) L.S.D.(P=0.01)			32.1 53.3		106.6 176.9	13.0 21.6
Six	0.0	540	220	-	500	160
	3.5	300	140	-	350	80
	5.0	160	146	-	322	65
L.S.D.(P=0.05) L.S.D.(P=0.01)		47.1 78.2	30.3 50.2		100.3 166.3	19.0 31.6

J = Juveniles, P♀ = Premature females, M♀ = Mature females, EM= Eggmass.

Table 9. Effect of sodium bicarbonate on the development of <u>Meloidogyne incognita</u> Race 2 on cucumber cv. Point Sett.

Time (week)	Concentration (mmhos/cm)	Stage of development				
		J_2	J_3/J_4	P♀	M♀	EM
One	0.0	185	346	6	-	-
	3.5	219	295	-	-	-
	5.0	211	116	2	-	-
L.S.D.(P=0.05)		39.3	17.0			
L.S.D.(P=0.01)		65.2	28.3			
Two	0.0	70	248	237	112	-
	3.5	114	310	120	25	-
	5.0	143	227	115	18	-
L.S.D.(P=0.05)		13.4	47.3	29.9	14.0	
L.S.D.(P=0.01)		22.2	78.5	49.7	23.2	
Three	0.0	12	240	147	245	42
	3.5	40	271	156	178	-
	5.0	90	230	30	90	-
L.S.D.(P=0.05)		10.6	53.7	37.0	39.9	
L.S.D.(P=0.01)		17.7	89.0	61.4	66.2	
Four	0.0	-	214	-	390	110
	3.5	-	279	-	265	66
	5.0	-	265	-	235	35
L.S.D.(P=0.05)		-	48.8		37.0	27.9
L.S.D.(P=0.01)			80.9		61.5	46.4
Five	0.0	140	10	-	470	155
	3.5	45	35	-	355	118
	5.0	60	65	-	320	85
L.S.D.(P=0.05)		8.9	13.5		32.0	19.9
L.S.D.(P=0.01)		14.7	22.4		53.1	33.1
Six	0.0	470	-	-	520	225
	3.5	285	10	-	415	180
	5.0	235	50	-	412	90
L.S.D.(P=0.05)		81.6			53.2	31.1
L.S.D.(P=0.01)		135.3			88.2	51.6

J = Juveniles, P♀ = Premature females, M♀ = Mature females, EM = Eggmass.

Table 10. Effect of sodium chloride on the development of *Meloidogyne incognita* Race 2 on cucumber cv. Point Sett.

Time (week)	Concentration (mmhos/cm)	Stage of development				
		J_2	J_3/J_4	P♀	M♀	EM
One	0.0	175	326	-	-	-
	3.5	245	293	-	-	-
	5.0	116	180	-	-	-
L.S.D.(P=0.05) L.S.D.(P=0.01)		56.3 93.3	49.6 82.2			
Two	0.0	100	210	240	96	-
	3.5	108	336	90	11	-
	5.0	145	356	40	-	-
L.S.D.(P=0.05) L.S.D.(P=0.01)		19.8 32.8	32.1 53.3	32.2 53.4		
Three	0.0	-	287	198	222	51
	3.5	31	258	122	147	-
	5.0	76	228	108	107	-
L.S.D.(P=0.05) L.S.D.(P=0.01)			8.8 14.6	16.2 25.6	56.0 93.0	
Four	0.0	-	160	70	381	114
	3.5	-	175	166	282	69
	5.0	-	116	262	177	40
L.S.D.(P=0.05) L.S.D.(P=0.01)			9.2 15.4	10.2 16.9	23.9 39.6	9.8 16.2
Five	0.0	183	8	114	396	168
	3.5	12	12	180	301	125
	5.0	7	21	199	292	90
L.S.D.(P=0.05) L.S.D.(P=0.01)		11.1 18.5	1.7 2.9	6.1 10.1	26.2 43.5	27.2 46.0
Six	0.0	387	135	-	495	238
	3.5	363	75	-	370	140
	5.0	350	15	-	350	110
L.S.D.(P=0.05) L.S.D.(P=0.01)		69.1 114.6	80.9 134.1		27.3 45.3	30.8 51.1

J = Juveniles, P♀ = Premature females, M♀ = Mature females, EM = Eggmass.

Development of juveniles in okra :

a. *M. javanica* :-

In okra roots, a number of *M. javanica* juveniles developed into J_3/J_4 stage in a week in all the treatments including control. After two weeks, pre-mature and mature females developed in all the treatments. But the number of pre-mature and mature females was lower in treatments than in control. During the subsequent weeks, number of females gradually increased and eggmass development occurred. Number of females and eggmasses were greater in control than in roots of $NaHCO_3$ treated plants. This difference was, however, significant only between control and 5.0 mmhos/cm at P=0.05 (Table 11).

A similar trend in development of *M. javanica* juveniles was also observed in roots of okra treated with both the concentrations of NaCl. Both the concentrations of NaCl suppressed the development of females and eggmasses. The number of females and eggmasses observed after three weeks and in subsequent weeks was significantly lower in NaCl treated plants than in control (Table 12).

b. *M. incognita* Race 2 :-

Development of juveniles of *M. incognita* Race 2 into females and production of eggmasses were significantly suppressed in okra roots by both the concentrations of $NaHCO_3$ and NaCl (Table 13 and 14).

Table 11. Effect of sodium bicarbonate on the development of *Meloidogyne javanica* on okra cv. Pusa Sawani

Time (week)	Concentration (mmhos/cm)	Stage of development J_2	J_3/J_4	P♀	M♀	EM
One	0.0	135	390	–	–	–
	3.5	187	285	–	–	–
	5.0	160	240	–	–	–
L.S.D.(P=0.05)		28.2	50.7			
L.S.D.(P=0.01)		46.5	84.1			
Two	0.0	125	376	105	40	–
	3.5	240	166	95	20	–
	5.0	255	116	90	5	–
L.S.D.(P=0.05)		39.5	44.9	31.9	3.0	
L.S.D.(P=0.01)		65.5	74.5	52.8	5.0	
Three	0.0	–	35	140	450	52
	3.5	–	70	145	360	35
	5.0	–	146	75	300	10
L.S.D.(P=0.05)			22.3	22.1	61.2	19.2
L.S.D.(P=0.01)			37.0	36.6	101.6	31.9
Four	0.0	32	8	–	510	115
	3.5	20	–	–	450	81
	5.0	10	–	40	390	35
L.S.D.(P=0.05)		24.2			122.1	62.3
L.S.D.(P=0.01)		40.1			202.5	103.3
Five	0.0	459	19	–	515	135
	3.5	400	–	–	465	105
	5.0	140	–	–	412	80
L.S.D.(P=0.05)		68.8			81.7	60.1
L.S.D.(P=0.01)		114.1			135.7	99.9
Six	0.0	415	310	–	538	195
	3.5	380	245	–	470	135
	5.0	370	130	30	415	125
L.S.D.(P=0.05)		68.6	37.2		54.6	64.4
L.S.D.(P=0.01)		114.1	61.7		90.6	107.0

J = Juveniles, P♀ = Premature females, M♀ = Mature females, EM = Eggmass.

Table 12. Effect of sodium chloride on the development of *Meloidogyne javanica* on okra cv. Pusa Sawani.

Time (week)	Concentration (mmhos/cm)	Stage of development J_2	J_3/J_4	P♀	M♀	EM
One	0.0	130	395	-	-	-
	3.5	190	265	-	-	-
	5.0	215	156	-	-	-
L.S.D.(P=0.05)		42.4	9.7			
L.S.D.(P=0.01)		70.4	16.0			
Two	0.0	150	360	110	35	-
	3.5	205	125	85	17	-
	5.0	235	118	-	24	-
L.S.D.(P=0.05)		35.4	17.8		5.1	
L.S.D.(P=0.01)		58.8	29.5		8.4	
Three	0.0	-	-	-	466	57
	3.5	-	-	-	400	30
	5.0	-	75	19	350	-
L.S.D.(P=0.05)					20.9	
L.S.D.(P=0.01)					34.7	
Four	0.0	10	-	-	500	118
	3.5	8	-	-	410	70
	5.0	-	-	-	380	50
L.S.D.(P=0.05)					15.1	28.6
L.S.D.(P=0.01)					25.0	46.0
Five	0.0	500	-	-	516	130
	3.5	300	-	-	450	85
	5.0	300	-	-	380	60
L.S.D.(P=0.05)		54.0			54.9	29.5
L.S.D.(P=0.01)		89.6			91.0	48.9
Six	0.0	400	300	-	530	190
	3.5	400	250	-	435	119
	5.0	310	150	-	385	95
L.S.D.(P=0.05)		215.4	25.3		81.9	26.2
L.S.D.(P=0.01)		357.2	41.9		135.9	44.1

J = Juveniles, P♀ = Premature females, M♀ = Mature females, EM = Eggmass.

Table 13. Effect of sodium bicarbonate on the development of *Meloidogyne incognita* Race 2 on okra cv. Pusa Sawani

Time (week)	Concentration (mmhos/cm)	Stage of development				
		J_2	J_3/J_4	P♀	M♀	EM
One	0.0	141	248	–	–	–
	3.5	176	258	–	–	–
	5.0	225	130	–	–	–
L.S.D.(P=0.05)		34.3	7.8			
L.S.D.(P=0.01)		57.0	12.9			
Two	0.0	167	356	125	30	–
	3.5	180	220	112	–	–
	5.0	215	238	6	10	–
L.S.D.(P=0.05)		28.0	21.4	3.4		
L.S.D.(P=0.01)		46.4	35.4	5.7		
Three	0.0	–	–	–	475	33
	3.5	30	–	11	432	18
	5.0	10	–	–	328	13
L.S.D.(P=0.05)					11.2	3.5
L.S.D.(P=0.01)					18.7	5.9
Four	0.0	–	–	32	496	95
	3.5	–	–	–	465	57
	5.0	–	–	10	385	52
L.S.D.(P=0.05)					23.2	17.2
L.S.D.(P=0.01)					38.5	28.5
Five	0.0	700	335	–	512	112
	3.5	300	170	–	485	90
	5.0	410	152	38	408	77
L.S.D.(P=0.05)		153.4	57.0		34.2	9.0
L.S.D.(P=0.01)		254.4	94.5		56.8	15.0
Six	0.0	1125	280	110	595	215
	3.5	600	380	–	510	195
	5.0	400	275	–	460	168
L.S.D.(P=0.05)		159.0	15.3		73.7	29.8
L.S.D.(P=0.01)		263.6	25.4		122.2	49.4

J = Juveniles, P♀ = Premature females, M♀ = Mature females, EM = Eggmass.

Table 14. Effect of sodium chloride on the development of *Meloidogyne incognita* Race 2 on okra cv. Pusa Sawani.

Time	Concentration	Stage of development				
(week)	(mmhos/cm)	J_2	J_3/J_4	P♀	M♀	EM
One	0.0	150	357	–	–	–
	3.5	200	195	6	–	–
	5.0	230	135	–	–	–
L.S.D.(P=0.05)		22.1	19.5			
L.S.D.(P=0.01)		36.7	32.3			
Two	0.0	154	340	116	35	–
	3.5	195	230	116	29	–
	5.0	230	212	45	–	–
L.S.D.(P=0.05)		45.4	26.3	43.2		
L.S.D.(P=0.01)		75.2	43.6	71.7		
Three	0.0	–	–	–	460	35
	3.5	–	–	–	400	12
	5.0	–	–	65	307	9
L.S.D.(P=0.05)					69.7	1.3
L.S.D.(P=0.01)					115.6	2.1
Four	0.0	2	–	–	490	90
	3.5	–	–	–	425	40
	5.0	–	–	–	350	11
L.S.D.(P=0.05)					27.2	14.2
L.S.D.(P=0.01)					45.1	23.5
Five	0.0	700	110	–	520	115
	3.5	800	–	–	460	78
	5.0	700	–	–	375	68
L.S.D.(P=0.05)		221.3			102.1	39.6
L.S.D.(P=0.01)		367.0			169.4	65.8
Six	0.0	1100	450	50	580	222
	3.5	400	300	–	490	155
	5.0	500	300	–	425	105
L.S.D.(P=0.05)		213.2	57.0		43.6	34.1
L.S.D.(P=0.01)		353.7	94.5		72.3	56.6

J = Juveniles, P♀ = Premature females, M♀ = Mature females, EM = Eggmass.

Effect of salinity levels and root-knot nematodes on growth of cucumber plants :

a. *M. javanica* :-

It is evident from Table 15 that both the concentrations of $NaHCO_3$ decreased the plant growth of cucumber. All plant growth parameter like length, fresh and dry weights were significantly suppressed.

Similarly *M. javanica* also suppressed the growth of cucumber plants as all growth parameters were significantly reduced. This reduction was slightly greater than the reductions caused by salinity levels. When the nematode and the concentrations of $NaHCO_3$ were added together, suppressive effect of the nematode was reduced. The growth performance of the plants was better than those plants inoculated with the nematode alone. For example, dry weight of plants inoculated with the nematode alone was 0.79 g but the dry weight of plants treated with 3.5 and 5.0 mmhos/cm of $NaHCO_3$ and inoculated with the nematode was 0.85 and 1.36 g respectively. A similar difference in other parameters like root, length, fresh, dry weights and shoot length, fresh and dry weights were also found (Table 15). The gall and eggmass indices (GI and EMI) were also lower in plants added with the salt concentration and the nematode (Table 15).

Sodium chloride concentrations used also caused reduction in plant growth of cucumber. The nematode also greatly reduced plant growth of cucumber. When both were together i.e.

concentration of NaCl and the nematode, the growth of the plant was comparatively better than of plants inoculated with nematode alone as found in case of $NaHCO_3$. The GI and EMI were also reduced by the NaCl concentrations (Table 15).

b. *M. incognita* Race 2 :-

The data presented in Table 16 show that all plant growth parameters were reduced significantly when cucumber was treated with two concentrations of $NaHCO_3$. The nematode inoculation resulted in great reduction in plant growth. When the nematode and concentrations of $NaHCO_3$ were used together, plant growth was comparatively better than of plants inoculated with the nematode alone. This effect on plant growth was found with both the concentrations of $NaHCO_3$. The growth was greater in plants treated with 5.0 than in 3.5 mmhos/cm. The salinity levels also affected the GI/EMI. In 3.5 and 5.0 mmhos/cm, GI/EMI were 5/4 and 4/4 in contrast to 5/5 with nematode alone (Table 16).

A similar trend in growth reduction was observed when sodium chloride was used. A better plant growth was found when NaCl concentration and the nematode were added together in comparison to plants inoculated with the nematode alone. No difference in GI and EMI were, however, found between the treatments (Table 16).

Effect of salinity levels and root-knot nematodes on growth of okra plants :

a. *M. javanica* :-

The two salinity levels (3.5 and 5.0 mmhos/cm) of $NaHCO_3$ significantly reduced the plant growth of okra also. *M. javanica*

Table 15. Effect of sodium bicarbonate and sodium chloride and *Meloidogyne javanica* infection on plant growth of cucumber cv. Point Sett.

Treatment	Shoot			Root			Total dry wt. (g)	GI/EMI*
Conc.(mmhos/cm)	Length (cm)	Fresh wt. (g)	Dry wt. (g)	Length (cm)	Fresh wt. (g)	Dry wt. (g)		
Sodium bicarbonate								
0.0	38.00	15.66	2.16	39.00	4.90	0.53	2.69	0/0
3.5	30.00	12.30	1.70	34.30	3.66	0.23	1.93	0/0
5.0	24.30	10.96	1.66	31.00	3.63	0.20	1.86	0/0
0.0 + N**	16.00	6.00	0.66	20.00	1.10	0.13	0.79	5/5
3.5 + N	19.00	6.90	0.69	21.60	1.30	0.16	0.85	4/4
5.0 + N	20.00	8.23	1.20	25.00	1.70	0.16	1.36	4/4
L.S.D.(P=0.05)	2.186	0.675	0.201	2.228	0.407	0.016	0.246	
L.S.D.(P=0.01)	3.108	0.957	0.285	3.169	0.576	0.023	0.408	
Sodium chloride								
0.0	38.00	15.66	2.16	39.00	4.90	0.53	2.69	0/0
3.5	31.00	10.33	1.30	31.00	3.40	0.30	1.60	0/0
5.0	25.16	10.33	1.20	30.00	3.30	0.26	1.46	0/0
0.0 + N**	17.33	7.10	0.90	19.66	0.81	0.13	1.03	5/5
3.5 + N	18.33	8.60	1.00	24.00	1.80	0.16	1.16	4/4
5.0 + N	20.33	9.73	1.00	26.00	1.90	0.20	1.20	4/4
L.S.D.(P=0.05)	1.225	0.935	0.196	2.138	0.133	0.077	0.259	
L.S.D.(P=0.01)	1.742	1.330	0.278	3.042	0.190	0.110	0.430	

* GI = Gall index; EMI = Eggmass index
** N = Nematode (*Meloidogyne javanica*)

Table 16. Effect of sodium bicarbonate and sodium chloride and *Meloidogyne incognita* Race 2 infection on plant growth of cucumber cv. Point Sett.

Treatment	Shoot			Root			Total dry wt. (g)	GI/EMI*
Conc.(mmhos/cm)	Length (cm)	Fresh wt. (g)	Dry wt. (g)	Length (cm)	Fresh wt. (g)	Dry wt. (g)		
Sodium bicarbonate								
0.0	38.00	15.66	2.16	39.00	4.90	0.53	2.69	0/0
3.5	29.00	11.00	1.60	31.00	3.00	0.27	1.87	0/0
5.0	26.00	10.50	1.60	31.00	3.00	0.20	1.80	0/0
0.0 + N**	15.00	6.10	0.60	20.00	1.40	0.10	0.70	5/5
3.5 + N	16.00	7.20	0.70	22.30	1.40	0.15	0.85	5/4
5.0 + N	18.50	8.20	0.90	25.66	1.50	0.15	1.05	4/4
L.S.D.(P=0.05)	3.030	0.837	0.222	2.060	0.404	0.033	0.248	
L.S.D.(P=0.01)	4.309	1.191	0.315	2.949	0.576	0.047	0.411	
Sodium chloride								
0.0	38.00	15.66	2.16	39.00	4.90	0.53	2.69	0/0
3.5	28.00	10.50	1.40	32.00	3.36	0.30	1.70	0/0
5.0	24.00	10.00	1.30	30.00	3.30	0.25	1.55	0/0
0.0 + N**	16.00	6.93	0.60	19.50	1.50	0.12	0.72	5/5
3.5 + N	16.00	7.00	0.70	22.00	1.80	0.12	0.82	4/4
5.0 + N	19.00	7.30	0.90	26.00	2.20	0.12	1.02	4/4
L.S.D.(P=0.05)	1.590	0.900	0.244	2.065	0.404	0.071	0.294	
L.S.D.(P=0.01)	2.262	1.280	0.345	2.937	0.576	0.101	0.489	

* GI = Gall index, EMI = Eggmass index

** N = Nematode (*Meloidogyne incognita* Race 2)

Table 17. Effect of sodium bicarbonate and sodium chloride and *Meloidogyne javanica* infection on plant growth of okra cv. Pusa Sawani.

Treatment	Shoot			Root			Total dry wt. (g)	GI/EMI*
Conc.(mmhos/cm)	Length (cm)	Fresh wt. (g)	Dry wt. (g)	Length (cm)	Fresh wt. (g)	Dry wt. (g)		
Sodium bicarbonate								
0.0	36.00	15.00	2.30	38.00	4.00	0.50	2.80	0/0
3.5	30.00	8.16	1.33	32.66	2.36	0.30	1.63	0/0
5.0	28.00	8.00	1.23	32.66	2.30	0.26	1.49	0/0
0.0 + N**	19.33	5.33	0.56	21.66	1.83	0.23	0.79	5/5
3.5 + N	20.33	6.16	0.90	23.66	2.19	0.23	1.13	5/5
5.0 + N	25.33	6.96	1.00	26.33	2.16	0.23	1.23	5/5
L.S.D.(P=0.05)	0.741	1.517	0.069	1.194	0.274	0.071	0.148	
L.S.D.(P=0.01)	1.050	2.158	0.098	1.698	0.389	0.101	0.245	
Sodium chloride								
0.0	36.00	15.00	2.30	38.00	4.00	0.50	2.80	0/0
3.5	33.66	10.33	1.66	32.33	3.90	0.33	1.99	0/0
5.0	30.00	10.16	1.46	29.66	2.66	0.33	1.79	0/0
0.0 + N**	20.00	6.50	0.90	21.33	1.33	0.16	1.06	5/5
3.5 + N	24.50	8.00	1.33	26.66	1.66	0.16	1.49	5/5
5.0 + N	26.50	8.66	1.40	29.33	2.23	0.23	1.63	5/4
L.S.D.(P=0.05)	1.355	1.171	0.432	0.920	0.630	0.071	0.683	
L.S.D.(P=0.01)	1.926	1.666	0.614	1.308	0.896	0.101	1.132	

* GI = Gall index, EMI = Eggmass index
** N = Nematode (*Meloidogyne javanica*)

Table 18. Effect of sodium bicarbonate and sodium chloride and *Meloidogyne incognita* Race 2 infection on plant growth of okra cv. Pusa Sawani.

Treatment	Shoot			Root			Total dry wt. (g)	GI/EMI*
Conc.(mmhos/cm)	Length (cm)	Fresh wt. (g)	Dry wt. (g)	Length (cm)	Fresh wt. (g)	Dry wt. (g)		
Sodium bicarbonate								
0.0	36.00	15.00	2.30	38.00	4.00	0.50	2.80	0/0
3.5	33.66	11.00	2.00	34.00	2.66	0.33	2.33	0/0
5.0	27.66	9.66	1.96	28.00	2.56	0.30	2.26	0/0
0.0 + N**	18.33	6.13	1.00	23.00	2.13	0.20	1.20	5/5
3.5 + N	24.33	6.46	1.10	25.00	2.33	0.23	1.33	5/5
5.0 + N	25.00	9.33	1.56	26.00	2.53	0.23	1.79	5/5
L.S.D.(P=0.05)	1.316	1.403	0.169	3.940	0.702	0.069	0.221	
L.S.D.(P=0.01)	1.869	1.996	0.240	5.609	0.976	0.098	0.366	
Sodium chloride								
0.0	36.00	15.00	2.30	38.00	4.00	0.50	2.80	0/0
3.5	31.50	11.16	1.76	30.66	2.93	0.30	2.06	0/0
5.0	29.83	12.00	1.83	30.33	2.93	0.30	2.13	0/0
0.0 + N**	18.00	6.56	0.83	24.00	1.23	0.16	0.99	5/5
3.5 + N	23.66	8.43	0.93	27.00	1.73	0.16	1.09	5/5
5.0 + N	27.00	10.00	1.53	29.00	1.80	0.16	1.69	5/5
L.S.D.(P=0.05)	0.759	1.225	0.060	2.049	0.256	0.089	0.122	
L.S.D.(P=0.01)	1.080	1.742	0.085	2.915	0.364	0.126	0.203	

* GI = Gall index, EMI = Eggmass index

** N = Nematode (*Meloidogyne incognita* Race 2) also reduced the plant growth but the reduction was greater than the salinity levels. The growth performance, however, was better when the concentrations of $NaHCO_3$ and *M. javanica* were together in comparison to plants inoculated with the nematode alone. No difference in GI and EMI between the treatments were, however, found (Table 17).

Similar results were also found when plants of okra were treated with NaCl concentrations alone, or inoculated with *M. javanica*. When both were present together, the supperssive effect of the nematode on plant growth was reduced (Table 17).

b. *M. incognita* Race 2 :-

Both the concentrations of $NaHCO_3$ decreased all growth characters of okra plants. When plants were inoculated with *M. incognita* Race 2, the growth parameters were also suppressed when nematode and any of the concentrations of $NaHCO_3$ were added together, plant growth increased with respect to salinity levels. A significant reduction was observed in total dry weight of plants in all the treatments in comparison to control. In GI/EMI, however, no difference was observed in nematode inoculated treatments (Table 18).

Similarly, a significant reduction in the growth performance as well as total dry weight was observed when plants were either treated with NaCl or inoculated with the nematode. But when both were added together, plant growth was better than those inoculated with the nematode alone (Table 18).

DISCUSSION

Sodium bicarbonate and sodium chloride demonstrated concentration dependent inhibitory effect on juvenile hatching of M. javanica and M. incognita Race 2. A concentration dependent toxic effect of salts on hatched juveniles of the nematodes was also exhibited. Inhibition of hatching in nematodes by salts has been recognised in some earlier works (Dropkin et al.,1958; Ellenby and Gilbert, 1958; Lal and Yadav, 1975). Dropkin et al., (1958) observed adverse effect of NaCl, $CaCl_2$ and KCl on hatching in M. javanica. Increase in the concentrations of salts resulted in decline in the number of hatched juveniles of M. javanica. Lal and Yadav (1975) also observed that soil leachates of varying salt concentrations inhibited juvenile hatching of M. incognita. Ellenby and Gilbert (1958) reported that juvenile hatching of Heterodera rostochiensis (= Globodera rostochiensis) decreased when eggs were exposed to saline media. The adverse effect of salinity on reproduction of free living nematodes has also been reported (Everard, 1960).

Penetration of juveniles (J_2) of M. javanica and M. incognita Race 2 was also impaired in roots of test plants - cucumber and okra-by both the salts and a direct correlation existed between the concentrations of the salts and the number of penetrated juveniles (Tables 3-6). These results are in accordance with those of Edongali et al. (1982). While studying the influence of NaCl, $CaCl_2$ and their combination on infectivity of M. incognita on tomato, they also found that juvenile penetration in roots was impaired by salts concentrations. Prot (1978a; 1978b; 1979) also found that juveniles of root-knot nematodes migrated towards lower salt concentrations regardless of the presence of a host. Soil environment around a host root is very important in determining the fate of nematodes. Edongali _et al_. (1982) stated that juvenile penetration is affected by the concentration of the salt and perhaps the type of salt in the soil solution. Juvenile penetration in the present study was slightly greater in presence of $NaHCO_3$ than NaCl (Tables 3-6). Greater inhibitory effect on hatching and higher mortality of the juveniles were also found with NaCl..

Wallace (1966) suggested that newly hatched juveniles remain active for a limited time of about 4-8 days. Edongali _et al_. (1982) observed in tomato treated with salts that penetration was maximum by the 7th day after inoculation. In present investigations, penetration was also maximum by the 7th day after inoculation in each case (Tables 3-6). Regardless of treatments, ingress of juvenile was slightly greater in okra roots than in cucumber. This might be due to difference in their degree of susceptibility to the nematodes. In screening of cultivars (Section II), on okra cv. Pusa Sawani reproduction factor of _M. incognita_ Race 2 was 10.80 and of _M. javanica_ was 7.28. But on cucumber cv. Point Sett, reproduction factor was 7.70 for _M. incognita_ Race 2 and 3.94 for _M. javanica_ (Tables 5,6 Section II).

This difference in reproduction factor shows that both the hosts were more efficient for *M. incognita* Race 2 than for *M. javanica*. Even under the stress of salts this difference in host efficiency was not disturbed.

Development of ingressed juveniles of *M. javanica*, *M. incognita* Race 2 was suppressed by the salts on both the crops. The development of females and production of eggmasses of the nematodes were delayed. The number of females that could mature and eggmasses produced were comparatively less under the salt stresses. This difference in numbers was concentration dependent. With an increase in the concentration, there was a corresponding decrease in number of females and eggmasses at all the time intervals in each treatment (Tables 7-14). Numbers of mature females and eggmasses after six weeks remained significantly low due to treatment of salts. These results are similar to those of Edongali *et al*. (1982). The results subtantiate their finding and show that penetration and post-penetration development of nematodes are greatly affected in plants growing under the stress of soil salinity. These effects were independent of the type of the salt involved. In general, it was also observed that some penetrated juveniles were still in different stages of development even after five weeks in cucumber roots irrespective of the treatments (Tables 7-10). However, in okra regardless of the treatments, all the penetrated juveniles were transformed into adults just after two weeks (Tables 11-14). This variation might be attributed to the difference in their degree of susceptibility to the nematodes.

Healthy condition of the host plant is important for the development of its parasites (Tyler, 1933). There are several reports indicating the suppression of plant growth by soil salinity (Maliwal and Paliwal, 1967; Ungar, 1974; Weimberg, 1975; Sheoran and Garg, 1978). However, extent of suppression to plants by salinization of the medium varies with the type of the predominent ions, their concentrations and the plant species (Stragonov, 1962; Weimberg, 1975). Plant growth of okra and cucumber were adversely affected. The higher concentration was more effective and the degree of suppression varied with the type of salt. The reason for suppression in plant growth as accounted by some workers is associated with the nutritional imbalances of major elements caused by salinity (Bernstein, 1964; Mengel and Kirby, 1978). Mengel and Kirby (1978) found that plants subjected to sodium chloride solution undergo changes in fine structure of cells and an exchange of K from the chloroplasts for Na from the soil solution. They further stated that sodium chloride salinity affects protein synthesis in young plants which leads to growth inhibition of meristematic tissue in young roots. Bernstein(1964) stated that sodium and chloride accumulation may be directly toxic to susceptibles species.

M. javanica as well as M. incognita Race 2 caused marked reduction in plant growth parameters of okra and cucumber. But in the presence of soil salinity caused either by $NaHCO_3$ or NaCl additions, the extent of this reduction in growth parameters of of both the crops was reduced and consequently the growth performence of plant was comparatively better than those inoculated with either of the nematodes alone. In general, the sum total of the reductions in growth parameters caused by the nematodes and soil salinity when acted individually, was greater than when both the nematode and soil salinity were together (Tables 15-18). The two adverse factors for plant growth did not work synergistically. Their interactive effect was not also antagonistic to each other. Salts were, however, toxic to the nematodes. The interactive effect of both the factors which proved beneficial for plant growth was apprently due to toxic effects of salts on nematodes in plant roots at different stages in their life cycle. These effects of salts on nematodes resulted in reduction of their damaging potentials. The root-knot nematodes seemingly did not influence the effects of salts on plant growth. It can be concluded on the basis of foregoing discussion that when plants grow under soil salinity stress the adverse effect of root-knot nematodes is reduced because of toxic effect of soil salinity on root-knot nematodes at different stages of their life cycle. This situation may be exploited for growing salt tolerant or resistant crops or their cultivars even in root-knot infested fields.

SUMMARY

Effect of different concentrations of NaCl and $NaHCO_3$ as soil salinity levels on hatching and mortality of juveniles (J_2) of root-knot nematodes, M. javanica, M. incognita Race 2 and on their penetration and development within the roots of cucumber and okra were studied in artificial treatments. The individual and combined effects of the salinity levels artificial created in soil and the root-knot nematodes on plant growth of both the crops were also assessed.

The concentrations of NaCl and $NaHCO_3$ i.e. 0.0, 1.5, 2.5, 3.5 and 5.0 mmhos/cm tested inhibited juvenile hatch and induced their mortality. A direct correlation in juvenile hatching and concentration of the salts was recorded. Highest inhibition in hatching was obtained in 5.0 mmhos/cm. Mortality was also highest in 5.0 mmhos/cm. Per cent mortality increased in all the concentrations with an increase in exposure periods.

Penetration of juveniles (J_2) in roots of cucumber and okra both was impaired by the salt concentrations. A direct correlation existed between the concentration of salts and the number of ingressed juveniles in the roots. The development of juveniles into adult females and production of eggmasses by females were delayed by both salts. The total eggmass production was also much less in salt treatments than in control.

Plant growth of okra and cucumber was suppressed by soil salinity. The higher salinity level was more effective in this respect. *M. javanica* as well as *M. incognita* Race 2 caused marked reduction in plant growth parameters of okra and cucumber. But in the presence of soil salinity created either by $NaHCO_3$ or NaCl additions, the extent of reductions in growth parameters of both the crops caused by the nematodes was reduced and consequently the growth performance of plant was comparatively better than those inoculated with either of the nematode alone. Apparently, the two adverse factors - soil salinity and root-knot nematodes - did not work synergistically. But soil salinity adversely affected the nematodes at different states of their growth and reproduction which in turn reduced the harmful effects of the nematodes on plants.

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